HANDICRAFT IN THE SCHOOL

GENERAL ARRANGEMENT OF SUBJECTS

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HANDICRAFT IN THE SCHOOL

VOLUME IV

A MANUAL-TRAINING CLASSROOM

Showing arrangement of benches, tool racks, and cupboards. The scholars are performing typical tool operations.

HANDICRAFT IN THE SCHOOL

VOLUME IV

Principles of Educational Woodwork

By

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PREFATORY NOTE

Manual-training teachers who fall short of full success, fail, as a rule, not through want of knowledge, but through inability to impart their knowledge and to cultivate the power of observation in their scholars.

Unfortunately manual instruction is too often looked upon as something apart from the work of the classroom, and it is urged that it has little or no correlation with the classroom subjects.

In this book an endeavour has been made to guide those who would be successful teachers of the subject in the method of procedure; while the principle of correlation is carefully set forth.

The opening chapters will assist teachers who are called upon to give advice concerning the provision and equipment of classrooms in which to teach the subject.

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GENERAL INTRODUCTION

By F. HANDEL THOMPSON, B.A., Inspector of Schools,
Johannesburg and Rand

Sir Joshua Fitch once wrote: "Drawing, representation, construction, and decorative work are educational processes as real as reading and writing; they touch as nearly the springs of all that is best in human character. They may have results as valuable and as far-reaching."

This, I maintain, is the attitude that every zealous educationist should take up on this important question of manual training. The days are past when we would urge the introduction of this subject into the school curriculum in an apologetic sort of way, and when the merest pretence at practical teaching had to be accepted as "a step in the right direction". By means of a distinct and definite course of manual work we find ourselves able to train and develop certain special talents and aptitudes for which no other subject of the ordinary school course adequately provides. We are enabled to supply a course of exercises which will provide food for thought, and, while interesting the child in its actual occupation, affords a valuable course of training in accuracy, carefulness, and in ordinary sequence. Moreover, the bench provides for the child, who is not passionately fond of books and of reading, just that incentive which is necessary to bring out all that is best, noblest, and most worthy of cultivation, and which goes to form true character.

but we must be orderly and methodical in our teaching plan. We must endeavour to correlate as far as possible those different branches of learning which appear as different phases of the manual instructor's task. It is for this reason that I welcome the appearance of Mr. Milton's book. It is written by a man of vast experience in this particular branch of educational work. It has stood the test of many years' experience both in the schools of London and of Johannesburg.

I have the greatest confidence in recommending this manual to all those who are really interested in the thorough and scientific teaching of this subject to our boys.

By W. KEITH MACGREGOR, M.A., L.C.P., Principal of the Training College, Johannesburg

In these days of kaleidoscopic change in the educational outlook, differences of opinion regarding the relative values of subjects proposed for study are inevitable, and not infrequently these differences are expressed with an amount of warmth which, however embarrassing on occasion, must without doubt bring joy to the heart of the educational enthusiast; for this warmth is the outcome of genuine interest, and in scholastic matters, as in all others, the warm enthusiast, even as an opponent, is always preferable to a deadweight of chilling indifference.

Probably Manual Training (Woodwork), more than any other subject, has given rise to divergence of opinion, and one is not by any means prepared to say that the war is now at an end, or that this subject has yet come to its own. Opposition to Woodwork as a school subject is discovered in varying degrees, from the mild protest of the indifferent teacher, who grumbles at "the waste of time", to the open hostility of the candid and well-meaning enthusiast, who "sees nothing in it".

It is possible that this opposition, wherever met, or in whatever form expressed, is due to an erroneous, because too narrow, conception of what education really is. It has been urged that Woodwork is a failure because so much of the work done according to scheme is *useless*—the boys are not making things *that can be directly used*; or otherwise, that they are making things *that cannot be directly used*; all of which, of course, sounds very well, and is very fallacious. Does the average boy or girl ever *directly* use, in after life, much of the arithmetic that he or she struggled through in school? or the composition in the classic form of "essay", or geometry, or the many other things that might be mentioned? Of course not. But how seldom is their presence in the timetable even questioned. They bear the stamp of antiquity; they are the peers of our educational system, with a long lineage extending into the historic past; and, whether useful or useless, their presence is looked on as natural and necessary by the very teachers who object to Woodwork as "a waste of time".

If, however, we take a larger view of education, e.g. that it aims at developing the power of *forming* and *expressing* ideas, then Woodwork at once assumes its proper place as one of our most valuable instruments. It is now an educational commonplace that ideas can be expressed by colour as well as by the regulation "composition". But they can also be expressed in cloth—which is only beginning to be recognized in our higher sewing classes—in plaster, in paper, pulp, &c. Why not also in wood? If the Woodwork exercise compel a pupil *to think* and subsequently *express his thoughts* (through the medium of wood), then it can justify its claim to recognition as an educational force; and any unbiased person who has narrowly watched a class performing woodwork operations must admit that both these activities are constantly called into play, and thus a child undergoing a scientifically arranged course in Woodwork stands as good a chance of being *educated* as does one whose time is confined solely to the so-called scholastic subjects.

The present volume on Woodwork is an attempt to secure the logical arrangement referred

to above. It has been written in the true educational spirit, its principles have been proved in actual practice, and of the value of the results there can be no doubt. If the book be used as Mr. Milton intends it should be—more as suggestions for the enthusiast than as a cast-iron rule of procedure for the casual instructor—it should prove invaluable. Without enthusiasm the best textbook in the world must fail, and this one—even though its methods have been tried and proved a great success in school and training-college work—could hope for no better fate. But, given enthusiasm and sound common sense on the part of the teacher, the following pages must prove a perfect mine of information and inspiration.

Part I

SCIENTIFIC PRINCIPLES OF EDUCATIONAL WOODWORK

CHAPTER I

Introduction

Education.—Many eminent writers have sought to define the term "education", and whilst they differ as to the ultimate meaning of the term, and the method by which its aim shall be accomplished, all are agreed that it is an instrument destined to develop to the full extent the faculties of man, and thus enable him successfully to carry out his duties in this world in whatever sphere they may lie. To this end it is essential that all the faculties which lie undeveloped in the "embryo" man must receive the careful attention of the educator, in order that they may be quickened and guided into right channels, that correct habits may be formed—habits of thought and action which shall make the individual a social blessing rather than an object of pity or a "social curse".

EARLY STAGES.—During the first years of the child's life it receives its education from the mother, whom nature has specially endowed with those educative powers which, properly applied, quicken and develop the child's æsthetic and other faculties. This early training at the "mother's knee" is all-important, and as time proceeds other educators assist in its further development.

THE SCHOOL AGE.—When the child first enters school we find it in full possession of its embryo senses. It can see, hear, touch, taste, smell; it has power to think and talk and act, yet how undeveloped do we find these senses. Now, it is these senses which the teacher has to develop, and such development must proceed by definite laws, if all are to be successfully developed to the full extent. *How is this to be accomplished?*

BODY, MIND, AND BRAIN.—The child possesses a body, the organs of which, in a healthy child, are all perfectly formed and capable of development. All may be uniformly developed or one may be specially developed at the expense of another. Steady uniform development of all the organs must be one of the aims of the teacher.

We know that the child possesses a brain and nervous system. It is through the agency of this nervous system and the senses that the child gains its knowledge of the material universe. The mind is that indescribable something which enables the being to control its various actions: by its agency we think; under its dictates we act. It must not be confounded with the brain, though the two are in some way inseparably connected. How important, then, becomes the duty of the teacher if the mind is to be so developed that correct habits of thought and action shall follow knowledge acquired by the senses.

MENTAL, MORAL, AND PHYSICAL FACULTIES.—The faculties possessed by the child are undeveloped, and it is the business of the teacher to aid in their development, because the process of development cannot be arrested, and if left unaided these faculties may develop into wrong channels, or such development may be sluggish and feeble. The possibilities of these faculties vary in each individual. All are capable of development, but in some individuals one or other of the faculties is capable of much greater development than others. Again, the faculties in various individuals are not always quickened by the same stimuli. The teacher must be careful, then, to so vary the stimuli that the individuality of each child under his care shall receive that particular quickening influence which shall awaken the child to a sense of his very being; careful to note the effect of such quickening and follow up the path thus discovered. "Every child's mind is a casket of gems; all that is wanting is the key." It is the duty of every teacher to endeavour to find this key. Where one teacher fails to find that key another may succeed. Where one school process fails to afford the clue another may yield the essential requirements. The lock to this casket may be "many levered", and when the right key is found all the levers are gracefully lifted together each in due proportion. So may it be with the child. Find the right key and you have a natural and proportional development of the faculties with which the individual is endowed.

THE EARLY SYSTEM.—There is little doubt but that early systems of education were knowingly or unknowingly based on the assumption that the child had a mind and brain, and that it was the duty of the educator to pack these with "information". No thought appears to have been given to the physical faculties possessed by the child, and little or no attention paid to training the children to acquire knowledge as the outcome of their experience by contact with the material world.

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Later Systems.—We now find that the child is treated in its entirety—body, mind, and soul—and the system of education is varied to meet the needs of, and provide for the full development of each, and this in no narrow sense. Instead of the child being "told" all that it is desired the child should know, it is led by natural methods to "discover" most facts for itself. In addition to the more purely "memory" exercises of the past, will be found the inclusion of practical subjects—subjects that call for physical exertion in order to overcome difficulties, the mastering of which, under the guidance of skilful teachers, enables the child to observe certain facts and deduce certain laws, the knowledge of which carries the scholar forward and enables him to approach new and more difficult problems with the conviction strong within him: "I will master it". Probably this is best summed up in the following words: "If a man make known to me some fact that has come under his observation, he is giving me information; if he make plain to me some proposition in science or art, he is giving me instruction; but if he employ the latter skilfully for the purpose of exercising my own faculties, then he is educating me". It is the duty of the teacher not merely to impart information and to instruct, but to *educate*. "A child's education must not be estimated as you do an apple tree, by what you can count, but rather as you do an oak, whose duration for hundreds of years, and fitness for valuable uses, are due to its slow, continuous, but almost imperceptible growth."

Manual Training.– All systems of education now include manual training in some form or other, but, unfortunately, it has come to be looked upon as something apart and distinct from the school work of the child. By many it is still looked upon as a pleasant form of recreation which may be entered upon or rejected at the will of the individual child, or which may be introduced or withheld from the curriculum of a school by the caprice of those in authority. Fortunately for the child the position is rapidly changing, and those who to-day act as leaders in the educational world are convinced that manual training is an essential factor in the education of a child.

Infancy of Manual Training.—Manual training is not a "new thing". The name may be new, but the practice dates back to the origin of man. By its aid man has at all times, and in all climes, acquired his real knowledge of the universe; by its aid have our great inventors made the valuable discoveries which enable us to live in ease and comfort to-day; by its aid were the material facts acquired which enabled the various natural laws

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to be defined. Only think of man's position to-day and compare it with his position in the Stone Age. To-day we have our steam engines, ships, telegraph, telephone, bridges, tunnels, &c. By what agency other than manual training were they acquired? Now this early form of manual training was not practised in our schools; it was left to the taste of the individual to engage upon, or neglect it, at will, with the consequence that only the genius came to the front and stood out as a monument among his fellow men.

INTRODUCTION INTO THE SCHOOLS.--When it was found necessary to modify the prevailing system of education, which, as we have seen, consisted solely of imparting information, the necessity for experiment became evident. What was to be done? What form should the change take? Practical work of some kind had to be introduced. By what name should it be known? The practical work introduced took many forms, among the most important of which was working in paper, cardboard, leather, clay, wood, and metal. These forms exist to-day, and they fall under the general title "Manual Training". In the upper classes working in wood was found in most instances to be that form which best lent itself to the desired end, but working in wood could in those early days be associated with nothing but "Carpentry"; and in the early days, be it understood, the idea was not the acquirement of knowledge through the agency of doing, its main aim was to develop "Handicraft". The pioneers of such a movement had perforce to adopt those methods common to carpentry, and the training certainly savoured of a "workshop training"; but such is not the case to-day. The work is no longer carpentry in its restricted sense, i.e. that of producing articles of wood, but it is practical education, forming an integral part of the school system, and having for its chief object the full and thorough development of the child's faculties. Manual training, like other subjects forming part of the system, may, and often does, provide the key whereby the casket of gems is opened. How often is it the case that a boy who is totally apathetic to all purely mental studies has his interests and desires quickened upon entering the manual-training classroom! What scope, too, is afforded for the application and testing of natural laws! Manual training is science in the truest sense of the word. Almost imperceptibly changes have been taking place in the methods applied to this subject. It is no longer a case of "What has the child done?" but "What has the work done for the child?" And who can measure this? The bright eye, the ready wit, the skilful hand, the thought-directed action, the intelligent application of natural laws to

accomplish a given end, are the manual-training teacher's reward for his efforts. What needs he more?

Educational Advantages.—Education advances by known laws, and it is the application of these laws which must be the aim of the manual-training teacher. The child enters the manual-training room keenly alive to the possibilities, and usually fully confident that "he can do it". He soon finds that he can do it, but that it is done badly. Why is this? Is it the child's fault? No. Whose fault is it? It is not a fault at all; it is merely that certain faculties are as yet not fully developed, and it is the duty of the manual-training teacher to carry on this developing work. In the lower standards the child has been taught to work intelligently with softer material, as clay, paper, and cardboard; now he is face to face with a harder form of matter, new or advanced laws have now to be applied, fresh tools handled which require the exercise of greater skill in their manipulation. Does the child possess this skill? If not, how can it manipulate these tools successfully? Now skilful manipulation implies perfect control over the particular muscles operating the given instrument. The actions involved are complicated; being new, there is nothing automatic or reflex in such actions. Here it is that the teacher shows his skill. Step by step he leads his scholars to see, think, and reason before deciding upon any given action. Step by step he leads his scholars to attempt successfully any given line of action. Step by step the scholars are led to acquire that confidence and self-reliance which alone makes man the master of matter. Call the work what you will. Call the things made exercises or models. Call them joints or rubbish, they are but means to an end. They do but contain the steps whereby the pinnacle is reached. These steps must be easy that all may ascend. There must be sufficient to enable the capable to continue climbing, ever nearing the pinnacle, which for each individual is only reached when he is capable of using all his faculties to the fullest and best. You cannot transport the individual; he must start from the base, he must make an effort, and the effort must be sustained. Each step in the ascent must demand just so much effort and exertion as the individual is capable of putting forth. You may by your teaching powers aid him in his climb, assist him over his difficulties, encourage him to continued effort, and lead him to success, but remember he must do the climbing. If you are careless in your teaching and make the child's task too difficult by endeavouring to make him take two steps at once, you may thus discourage and retard his progress.

What does this making of "things" in wood or other substance mean to

the child? We have only to look within for the answer, which cannot be expressed in words. Who has not experienced that feeling of delight at the thought that some difficult piece of work, demanding all the effort of which you were capable, mental and physical, has at last been successfully accomplished! With what pride do we view such work! What then must be the child's feelings when it sees before it a "complete thing" and can truly say "I made it"! "It is the outcome of my own effort." "Teacher guided me, but alone I did it." Is not this the true germ of manhood? Is not manual training capable of assisting in the development of this germ?

Who shall be the Teacher?—Much discussion has arisen on this point Naturally, at the outset of this experiment, the teacher had to be a man possessing the necessary skill. This was the carpenter. But is he a teacher? He may not have been, but is it impossible for him to become one? If it be the class teacher, does he possess the necessary skill? He may not, but is it impossible for him to acquire that skill? These are problems which each must solve for himself. The vital point is that all who teach must be teachers, and he who is interested in his subject will surely leave no stone unturned to attain his end. All must study child life. Practice and experience will alone make perfect. Failures must be left to the mercy of the authorities that be. One thing is certain, we cannot afford to hinder the child by placing over him an inefficient teacher, be he trained or untrained.

CHAPTER II

Classrooms and Equipment

Too often is it the case, when considering the question of new schools that manual training is overlooked, or it is even thought by some that "anything is good enough", with the result that any old building—be it suitable or unsuitable, well or badly ventilated and lighted—is considered fit for the purpose.

The children have first to be considered, and if they are to spend a portion of their lives in these rooms it becomes the first duty of the authorities, at all costs, to see that these rooms afford a healthy environment for the children. The work, calling for physical exertion and the discharge of effete matter from the body, necessitates special attention being paid to the ventilation of

the room. No fixed law need be made concerning the shape and arrangement of a room, but the following points need attention.

Rooms.—When possible it is advisable that the following rooms be provided:—

(A.) Entrance Lobby.—Provided with hat and cloak pegs, wash basins (about one to every five scholars) with water supply and waste.

It is essential that the lobby be well lighted and ventilated. During wet weather the hats and coats are often very wet, and it is necessary that the vapours given off from such clothing should not enter the classrooms. The lobby should be large, to prevent overcrowding, and the entrance doors should swing in both directions.

(B.) Bench Room.—The size of this room will depend upon the number of bench places for which provision has to be made. (Twenty is the maximum for any one teacher; thirty if assisted by a junior teacher; forty provided two qualified teachers are present.)

The shape of the room is best determined by allowing for the benches to form two rows down the room, the benches having their ends directed towards the windows to ensure good light to the workers. Assuming that the room is arranged in this manner, and that each bench is approximately 5 ft. long and 3 ft. wide, the *width* of the room will require to be 24 ft.; this will allow for a central passage 6 ft. wide, and passages at each side 4 ft. wide. The length will be determined by the number of benches; the space between them should be 3 ft. (more if possible); thus each bench with its working space occupies 6 ft. run of floor. Working space must be allowed for the back row of benches, also space for teacher's desk, demonstration bench, cupboards, &c.

There should be a teaching space of at least 10 ft. in front of the class. On this basis a bench room suitable for the accommodation of twenty scholars would be 42 ft. by 24 ft.

Windows and Ventilation.—The windows should come as nearly as possible opposite the ends of the benches, and have their sills about 6 in. higher than the top of the benches; the lower part of the windows should have double-hung sashes with *deep* guard bead at bottom to allow for the inlet of air at the meeting rails during wet or cold weather (fig. 1). The top part should be so constructed that the sashes open on the louvre principle (fig. 2).

Provided good use can be made of the windows in this way there is little need to consider any further provision for inlet of air; but should these not be

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fully available for the purpose, then *Tobin's tubes* should be arranged at intervals around the room; these have the advantage that in smoky or foggy weather the air can be filtered before entering the room.

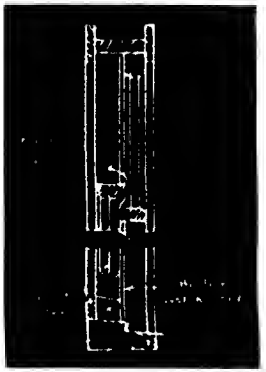

Fig. 1

Air outlets are essential. These should be on the mica-flap principle, and plentifully arranged about 9 in. from the ceiling. Provided no rooms exist above the classroom it is better to arrange for an "open roof" with outlets in the ceiling, and "Boyle's" extractors in the roof above. It is essential that the children should be protected from draughts. These points carefully attended to will preserve the children from headaches, faintness, or exhaustion by overheating in summer.

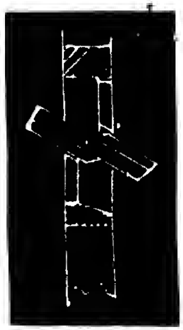

Fig. 2

Blinds should be provided to all windows. Brown holland is the most suitable material, for whilst shutting out excessive sunshine it does but serve to subdue the light.

Entrance doors should be large and swing in both directions.

Fig. 3

FURNITURE: *Work Benches, and Tool Racks.*—Many forms are now in existence, each with its relative merits, and it is difficult to claim that any one form is perfect. Special circumstances, too, must be considered. In cases where the classroom is devoted entirely to manual training the open

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dual bench with tool racks placed between each pair of benches, as shown in fig. 3, has many advantages.

Where the classroom may at times be used for purposes other than manual training, and possibly by teachers not responsible for the tools and equipment of the room, it becomes necessary to arrange for all tools to be under lock and key; this is often accomplished by the provision of cupboards under the benches. The principal disadvantages of this system are:—

(*a*) All tools are hidden from view and not readily accessible to the scholar.

(*b*) It is difficult for the teacher to exercise that supervision which is essential to ensure that all tools are kept in proper order.

(*c*) Cupboards of this description usually harbour dirt.

(*d*) The doors swinging into the bench walk impede the free movements of the scholar.

Advantages of the Central-rack System:—

(*a*) All tools are readily accessible to the scholars.

(*b*) They are easily supervised by the teacher.

(*c*) Missing tools are at once detected.

(*d*) Being exposed they can more easily be kept clean.

(*e*) They offer no impediment to the scholar when at work.

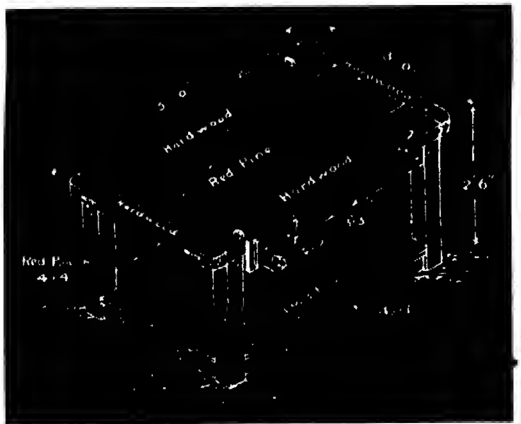

Fig. 4

The Bench.—Rigidity is an essential feature. The most suitable size is 5 ft. long, 3 ft. wide, and 2 ft. 6 in. high. It follows naturally that different individuals require benches in keeping with their height. The top surface of the bench should be in line with lower portion of the buttocks. It would be advisable to vary the

height of the benches in a room from 2 ft. 4. in. to 2 ft. 8 in., placing the lower benches to the front and the higher benches to the back of the class. They should be provided with substantial vices (fig. 4).

The vice is a most important feature of the bench. Various forms exist, and it is most economical in the end to furnish all benches with good vices at the outset.

Instantaneous Grip Vice.—These are the best in the market, and though the first cost is relatively high, this is more than compensated for by the saving in time and worry, and the effectiveness of their grip. They should be lined with hard wood.

Parkinson's Vice.—This is an excellent vice, but the spring blade actnating the instantaneous grip action is apt to get out of order. It is certainly to be preferred to the oldfashioned screws.

Iron Screws.—These are a great improvement on the old wooden screw but entail much loss of time, and the grip afforded is not "parallel".

Wooden Screws.—These, though still much used on account of their "cheapness", are very unsatisfactory. Like wooden ships, they should be regarded as "things of the past".

Central Tool Racks.—These need no special description: the accom-

panying figure (5) explains all details, and the number and arrangement of the tools can be varied according to special requirements.

Cupboard for Special Tools.—A cupboard should be specially fitted, and placed in a convenient position in the room, to hold all extra tools. The dimensions and internal fittings will depend upon the nature of the special tools stocked. The scholars have free access to such a cupboard during the execution of any special work calling for the use of such tools as the cupboard contains; all tools should be returned to the cupboard at the close of the lesson by the user

Work Cupboards—"Lockers".—Sufficient accommodation should be provided to hold the work of each separate class attending the centre. Many systems are adopted, but the best consists of providing a locker for the work of each class; these should be contained in one or more cupboards, each locker being approximately 2 ft. long, 15 in. high, and 16 or 18 in. deep (front to back). These should be provided with locks.

Cupboards for Storing Finished Work.—The size and arrangement of such cupboards will vary according to the nature and amount of work executed. Any ordinary cupboard will answer for the purpose.

Show Cases.—One or more show cases should be provided, in which suitable specimens of the scholars' finished work can be exhibited, the main purpose of exhibiting such work being to encourage emulation.

A case is also necessary in which to store specimens of wood, &c., to be used during the lessons on timber, tools, &c. All specimens should be properly labelled and classified, and scholars should be encouraged to examine such specimens.

General Stock Cupboard.—One such cupboard is necessary for the purpose of storing articles of a general character.

(C.) Drawing Classroom.—It is common in manual-training classrooms for scholars to prepare their drawings on the work bench. Whilst this may seem economical, it is detrimental to the scholar, and the conditions are not conducive to the production of really satisfactory drawings.

Disadvantage to the Child.—The scholars have to stand for a considerable time in a stooping position, causing the back and legs to ache.

Disadvantages to the Work.—(*a*) Owing to the stooping position occupied by the scholars they have not complete control over the drawing instruments.

(*b*) The tired feeling, caused by constant standing and stooping, leads to careless work.

(*c*) The benches cannot possibly be kept as clean as a drawing desk or

table should be kept, and in consequence the drawings cannot be kept clean and tidy.

(*d*) Where the benches are used for the purpose of a drawing table, all scholars must cease drawing at the same time, be their drawing finished or not. The provision of a special classroom and desks enables scholars to complete their drawings without being disturbed by the movements of other scholars.

Advantages of a Drawing Classroom.—(*a*) The desks are specially constructed for the purpose, and avoid the necessity for the scholars occupying a stooping position.

(*b*) Stools are provided, thus enabling the scholars to occupy a position of rest during the lesson, which is conducive to the production of more careful work.

(*c*) There is an air of special cleanliness about the room which unconsciously influences the scholars to put forth their best efforts. "Environment makes the man."

(*d*) Scholars can sit quietly and complete their drawings whilst the remainder of a class is at work in the bench room.

(*e*) In centres where more than two sessions per day are worked, the provision of a drawing classroom enables the time for each class to overlap, thus reducing the total number of hours per day which the teachers at such centres are compelled to be present.

Thus, in a centre working three sessions per day, of two hours duration, and having two teachers, the times of the classes could be arranged as follows:—

Group A, 8·30 a.m. to 11 a.m. Group B, 10·30 a.m. to 1 p.m. Group C, 12·30 to 3 p.m.

Group A would be drawn from the school on the premises.

Group B would be from schools in the immediate neighbourhood.

Group C would be from schools somewhat removed from the centre.

It is a common practice to devote only two hours per week to the work; this is insufficient time in which to do justice to all branches of the subject. The above arrangement would give the scholars more time for the work without distressing the manual-training teachers. During the middle period the teachers would relieve each other for the purpose of affording a luncheon interval.

Dimensions of Drawing Room.—These will vary according to the number of scholars and the particular type of drawing desk adopted. Designs for desks are shown in figs. 6 and 7.

Assuming that the drawing classroom is a continuation of the bench room, having a width of 24 ft., the most convenient form of desk would be that to accommodate three scholars, thus giving a central passage 3 ft. wide and side passages 18 in. wide. Each row of desks, including space for the stools, will occupy about 4 ft. run of floor space. Thus with twenty-four scholars in the class there would be four rows, occupying 16 ft. run of floor space, and, allowing for a teaching space of 10 ft., the room would require to be 26 ft. long.

Position of the Drawing Room.—The room should form a continuation

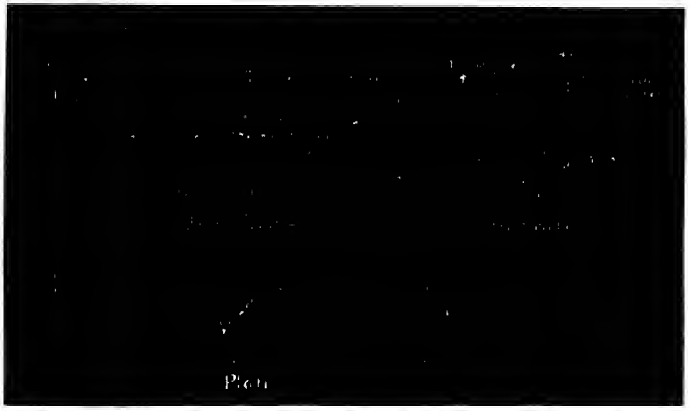

Fig. 6

of the bench room, and be separated therefrom by means of a partition having the top portion of glass.

This may have the effect of producing a long, narrow building, but this difficulty can be overcome by arranging the rooms side by side, when it must be borne in mind, however, that one side of the bench room will have no windows—a serious defect only partly compensated for by the insertion of lights in the roof.

Lighting and Ventilation.—The room should be particularly well lighted, and a top light is a great advantage. The ventilation of the room should be carried out in a manner similar to that prescribed for the bench room.

GENERAL FITTINGS: *Drawing Desks.*—A simple form of drawing desk is

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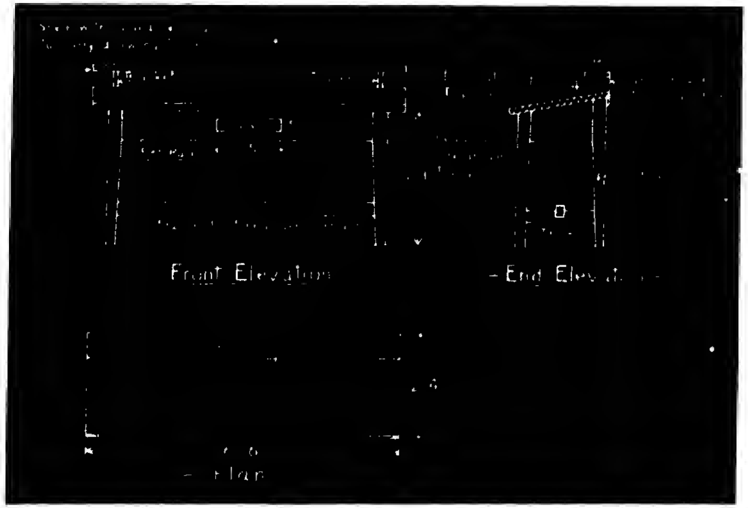

Fig. 7

shown in figs. 6 and 7. In design they are similar; the length can be varied to suit the conditions of the room. The desks are 2 ft. 9 in. high. Thus scholars have to occupy a semi-standing position. The slope of the top should not exceed 10 degrees, and the small shelf on the top provides accommodation for the drawing tools whilst work is in progress. The provision of a drawer is not essential, but when introduced it enables the smaller tools, common to the desk, to be locked away at the close of the lesson. The class monitor should be held responsible for the supervision of such drawers.

Fig. 8

The Stools.—These are small but they afford just the required amount

of rest to the scholar, at the same time preventing general shiftiness. (See fig. 8.)

Blackboard.—A large sliding blackboard should be provided, together with a platform from which to teach.

Cupboards for general stock, and *racks* for storing drawing boards and T-squares, are essential.

A *teacher's demonstration table* is a necessity, and may be in the form of an ordinary table.

(D.) STORE ROOM.—It is essential that a room be provided in which to properly store the timber. It should be large enough to permit of all kinds and thicknesses of timber being separately grouped and stacked in such a manner that air can circulate freely about the planks; at the same time each stack should be readily accessible.

The room should be well ventilated to carry off any moisture arising from the continued seasoning of the timber.

To leave the timber standing in the classroom, as is sometimes done, gives to the room a very untidy appearance, which is detrimental to the best interests of the scholars.

(E.) TEACHER'S ROOM.—Whenever possible a small room should be provided for the use of the teacher. This should be furnished with desk, chairs, and a cupboard or shelving for books and stationery.

General Remarks: WARMING.—It is often urged that, as manual work is of a physical character, it is not necessary to make provision for warming the room; this is a fallacy. The temperature of the manual-training room requires to be but little below that of the ordinary classroom.

Assuming that the work is of a physical character, it does not follow that at all times all scholars will be performing such tasks as call for sufficient physical effort to keep the blood in rapid circulation. Hence provision should be made for warming all rooms in cold weather.

Open fireplaces are most healthy but not most economical. Where this form is adopted care must be taken to use a guard surrounded by gauze as a safeguard against fire. The gauze prevents the heat radiating freely into the room.

Hot-water Radiators.—These are the most effective, and provided they are directly associated with the air inlets, and so situated that filth cannot accumulate in inaccessible parts, they are, next to open fireplaces, most healthy.

Slow-combustion Stoves and Oil Stoves.—These certainly warm the

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4 SCREWDRIVERS, 4 in., box handles (cabinet pattern).
2 each, SPOKESHAVES (best boxwood), 2, $1\frac{3}{4}$, $1\frac{1}{2}$ in.
5 SPOKESHAVES, Stanley's iron (double cutters).
20 TRY SQUARES, $4\frac{1}{2}$ in., ebony stocks.
2 „ $10\frac{1}{2}$ „ „

NAILS—

Best Oval Wire

2 lb. each, 2, $1\frac{1}{2}$ in.
3 „ 1, $\frac{3}{4}$ in.
1 „ $\frac{5}{8}$, $\frac{1}{2}$ in.

Brass Escutcheon Pins

2 lb. each, $1\frac{1}{4}$, 1, $\frac{3}{4}$ in.

SCREWS—

1 gross each, 2 in.-12, $1\frac{1}{2}$ in.-12, $1\frac{1}{4}$ in.-12.
2 gross each, 1 in.-8, $\frac{3}{4}$ in.-6, $\frac{5}{8}$ in.-4, $\frac{1}{2}$ in.-4.

Brass Screws (round headed)

2 gross each, $\frac{3}{4}$ in.-4, $\frac{5}{8}$ in.-3, $\frac{1}{2}$ in.-3.
2 gross HOOKS, $\frac{1}{2}$ in., brass, square shouldered.
1 STOVE and TRAY for gluepot.

The foregoing list represents an economical equipment for a class. The list can be revised or supplemented to suit the particular course of work it is proposed to adopt. All tools should be of the very best quality; inferior cheap tools lead to unsatisfactory work and prove more costly in the end. Economy and efficiency should be combined. Economy at the expense of efficiency is but false economy.

CHAPTER III

Class Management and Discipline

In a well-ordered manual-training class there must be perfect discipline. The scholars, in manual-training classes, by virtue of the special character of the work carried on, must have greater freedom, hence the necessity for strict discipline. Whilst perfect discipline is essential, the teacher must not become the slave of any particular system. Discipline is the means whereby the teacher gains his purpose and leads his scholars to the desired goal with the greatest ease to all concerned, and with the greatest amount of good to the scholars under instruction. It is a means to an end, not an end in itself.

The Teacher.—The influence of the teacher upon the children under his care is more powerful than is usually recognized. Children observe every movement of the teacher. They watch his incoming; they observe his movements in the class, listen to his discourse, note his moods, observe

his habits, and consciously or unconsciously tend to follow his example. This being the case, how necessary is it that the teacher should watch himself.

Order and Neatness.—If habits of orderliness and neatness are to be encouraged in the children, the teacher must see that in all his doings he himself is orderly and neat. The room and all that pertains thereto must be arranged and kept in an orderly manner. There should be a definite place for everything; the scholars should know that place and be taught to keep things in their places. During the lessons many tools are required; these should not be strewn about the bench in an indifferent manner. The teacher, whilst demonstrating to a class, should quietly, and without ostentation, so arrange his tools that the scholars see at once the value of such an arrangement, and how readily each tool comes to hand when required for use. The bench should not be overloaded with tools, but as each ceases to be required it should be returned to its place in the rack or cupboard. When passing round the class, call attention to any untidiness connected with the benches. At the close of a lesson scrutinize all racks carefully and see that the tools have been properly put away. The scholars should brush all parts of the bench, thus leaving it clean and tidy for incoming pupils.

Surplus material from a lesson should be returned to the storeroom. Nothing gives to the room a more untidy appearance than a number of short ends and sawn planks distributed at random about the sides of the classroom.

All work and books should be carefully collected and stored in suitable cupboards at the close of each lesson, and the distribution and collection of such should be the duty of the monitors.

At the close of a lesson scholars should write their names and bench numbers on every piece of work, to facilitate future distribution.

Each scholar should provide himself with an apron, to which should be attached a label bearing his name, bench number, and class.

Punctuality.—The teacher should be in his place from ten to fifteen minutes before the commencement of the lesson. When teachers form the habit of coming late, it is small wonder that their scholars attach little importance to habits of punctuality. The teacher being in his place before time enables the monitors to enter the classroom and distribute all books, work, and aprons before the scholars enter; thus the real work of the class can be proceeded with without loss of time. Another advantage gained by the teacher is that he is enabled to prepare any material or arrange for

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special requirements of such a class. Where teachers enter the classroom with their scholars, much valuable time is wasted in such distribution of material or such special preparation. Not only is there a great waste of time, but the scholars, having nothing to do in the meantime, become restless, and the teacher disconcerted. Once this takes place in a class there is little hope of silent, steady work during the lesson.

All lessons should start at the time appointed, and the same punctuality should be observed at the close of the lesson. Concerning the question of punctuality, co-operation is needed on the part of the teachers in the schools from whence the scholars are drawn. Many teachers form the habit of keeping scholars to do *special* work when they should be in attendance at the manual-training lesson, with the result that when a class is lined up for entering the room all are not present. The scholars instinctively take this as a mark of disrespect for the subject, and are tempted to think: "If teacher does not care whether I am present to time or not, then why should I care?"

All latecomers should be carefully questioned concerning the reason for lateness, and a record kept. Absentees should be carefully enquired after, and the seriousness of such absence pointed out to the scholars. The successful working of a class is often ruined by scholars who attend irregularly.

The attendance of scholars at manual-training lessons should in no way be interfered with by the introduction of special events, as sports, special drills, &c. A time is appointed for the manual-training lessons, and nothing should be allowed to interfere with their due course.

Monitors and their Use.—The successful teacher is usually the one who does least for his class. He acts as a director, and by the judicious selection and guidance of monitors secures that most of the work—other than absolute teaching—is done by the scholars. This has a very important bearing upon the class. Boys love power, therefore there is, in the promotion of scholars to act as monitors, a valuable incentive to work. The pupils are made to realize that they are themselves responsible for the general condition of the room and its orderliness. This arrangement enables the teacher to think and act calmly, and to avoid that semblance of rush and hurry which is so fatal to successful teaching.

Monitors should be in their places, if possible, ten minutes before the incoming class, and have everything in readiness for work.

Entry of Scholars.—Before entering the classroom the scholars should "line up" in readiness to enter the room. Whilst on line the teacher should

rapidly review each scholar, noting such points as untidiness of person, dirty boots, hands, face, &c. This may appear to be a minor point, and no business of the manual-training teacher, but remember the boys are for the time being in charge of the manual-training teacher, who must leave nothing undone which will conduce to the general wellbeing of the class. The scholars may be poor, but poverty is no excuse for carelessness or filth.

Scholars should march in an orderly manner through the lobby, and a monitor should be appointed to see that hats and coats are hung up tidily.

When the scholars enter the room they should march quietly to their places and remain at attention for ensuing orders. Where scholars are allowed to enter the room indifferently, chaos prevails, and the teacher's time and energy are expended in securing that which should have existed from the first—Order.

Registration.—Class registers should be called and attendances recorded in keeping with the instructions laid down in the Code. Here again correct habits on the part of the teacher show themselves and have a silent influence on the scholars.

Distribution of Lessons.—All lessons should proceed in a methodical manner.

A certain portion of time should be allotted to drawing. This is best taken at the commencement of the lesson, before the physical condition of the scholars has become affected by the exertion of working at the bench. Not more than one-fourth the total time should be devoted to drawing.

The change from drawing to benchwork should be orderly and quickly effected. All drawing materials should be carefully passed, according to given signals, collected, and placed in their proper places by the monitors.

When starting benchwork it is a good plan to call all scholars round the demonstrating bench, and if necessary give any demonstrations that may be required. Should no demonstrations be necessary, the class should be carefully questioned concerning the method of procedure for the particular work on hand, and any information of a general character which may be necessary should then be given. This arrangement enables all scholars to settle quickly and quietly to their work without confusion.

During the benchwork lesson the scholars should be interrupted as little as possible. Much time is wasted by repeatedly stopping the whole class. This should as far as possible be done only when a demonstration is about to be given, or when the lesson is about to close.

Lessons on Tools, &c.—Much of this work will be performed during

the demonstrations, but it is a good plan to set apart ten minutes at the close of every lesson for this purpose.

Marking Work and Keeping Records.—All work executed by the scholars should be carefully marked, and such marks entered in a class record. Properly handled this has a wonderful effect upon the scholars. They try to gain good marks and are anxious to take a good place in the class.

A diary of the work done during every lesson should be kept, noting lessons taken and inserting general remarks upon each individual class. These records are a valuable guide to the teacher in arranging his work for the class, and are invaluable to the inspector who wishes to analyse the work of a class in a thorough manner.

Whenever possible the work should be marked in the presence of the scholars in order that all errors may be pointed out to them and a kindly word of encouragement given for future effort.

Aids to Discipline.—The most valuable aid to discipline lies in the careful organization of work by the teacher.

There must be a definite but simple system of laws with which the scholars are early acquainted. These laws must be constant and not subject to change according to the mood of the teacher. They must be impartially applied.

All scholars should be kept constantly employed; nothing leads to poor discipline more quickly than "having nothing to do".

Orders must be simple and promptly executed, one at a time. They should not be repeated, or given in a loud tone. The teacher must be consistent and just in all his dealings with the scholars.

Exercise kindness combined with firmness.

At no time must scholars be allowed to become unduly familiar, yet hey must feel that in the teacher they have someone to whom they can ppeal for sympathy and direction.

The expression of the teacher's face is a valuable aid to discipline. A leasant look should reward right doing, whilst a stern look should be ıfficient to check any wrong action.

Use your voice as little as possible: with a well-trained class a look ill suffice.

Any system of signals by means of the bell should be simple and definite. ıe voice should not accompany the bell.

Avoid noisy threatenings. If the law be broken, call the particular

offender to order, do not blame the whole class for the offence of an individual.

Where corporal punishment becomes necessary, the scholars must realize that the laws demand its use as a deterrent and that it is not administered to gratify the personal feelings of the teacher.

Scholars Talking.—It is not advisable to insist on perfect silence during the benchwork lesson. Provided the scholars do not become too noisy, the fact that they are interchanging remarks concerning their work should be recognized; scholars often help one another to overcome little difficulties which may probably have been overlooked by the teacher. The interchange of ideas in this way, and the inspection of another boy's work, often encourage the weaker ones to renewed effort.

Such talking, where permitted, must be under perfect control by the teacher. It should cease instantly when the bell rings, and it should be within the teacher's power to withhold the privilege temporarily.

On no account should scholars be allowed to leave their places for the purpose of holding a discussion with their companions. Such a procedure is indeed a sign of bad discipline.

Corporal Punishment.—It is very rare that corporal punishment becomes necessary in the manual-training class, yet scholars should realize that the teacher has the right to administer such should it become necessary to have recourse to the same as a deterrent in certain offences. The knowledge that the teacher possesses this power should be of greater service to the teacher than the exercise of such power.

The exercise of corporal punishment is degrading in a measure to both teacher and scholar, and the teacher who is constantly exercising this right soon forfeits the respect and goodwill of his scholars. Such a teacher cannot guide, lead, and control by the exercise of his personality, but secures so-called order as the outcome of fear.

Where corporal punishment becomes essential, the teacher should administer it in a cool, unimpassioned manner, strictly conforming to the regulations as defined by the Code under which he works.

Remember, corporal punishment is your "big gun"; when it is fired, you have nothing to fall back upon.

Advantages of Good Discipline.—It secures to scholar and teacher alike the greatest amount of comfort and enables work to proceed in a quiet, orderly manner which is pleasant to all, and none appreciate good discipline more than the children themselves once the habit has been formed.

Where good discipline exists the work proceeds with ease, and many

lessons which would under other circumstances appear mere drudgery become the scholars' pleasure.

It has a far-reaching effect on the future of the children, and they become amenable to the more rigid discipline of commercial life.

Without its aid the intellectual development of the child is seriously hampered.

CHAPTER IV

Drawing

INSTRUMENTS AND THEIR USE

Introduction.—The important bearing which drawing has upon all modern arts and crafts is now so well understood that for a boy to leave school without a knowledge of the subject is to handicap him heavily at the outset of his commercial career.

The inclusion of drawing in a manual-training course should have for its ultimate object something more than teaching a boy merely to draw. It should develop his powers of observation, teach him to think and reason, make him careful and accurate, and train his æsthetic faculty.

The greater part of the drawing employed in the manual-training room is of the type known as mechanical drawing, but it need not, and should not, be confined entirely to this branch.

It will usually be found that boys enter the classroom with little or no knowledge of the principles underlying the production of such drawing, or of the use and method of manipulating the tools commonly used in its production. This being the case, it is the business of the teacher to first explain the nature and method of using each drawing instrument as the necessity for its use arises.

Demonstrations in Drawing.—Scholars more readily understand a demonstration if it be given under exactly similar conditions to those under which they are expected to work. The teacher should therefore, in addition to any drawing or sketch he may place upon the blackboard, also draw the exercise in the drawing book or on paper by the aid of drawing board and T-square, in just the same manner as the scholars will have to prepare their drawings. Demonstrations of this kind are of much

greater importance than any amount of blackboard work in making clear the correct principles underlying the use of the drawing tools.

Necessity for Drawings.—When introducing the subject to a class it should be made quite clear that all scholars must prepare their own drawings, which shall show all the dimensions of the object to be made, in order that, as the work of making the object proceeds, it will be possible to obtain, as the necessity arises, the dimensions of any particular detail.

Method of Preparing such Drawings.—The drawings should on no account be mere copies from prepared drawings or diagrams. The teacher must take a wider view of the subject than that of producing mere copyists.

In the early stages the drawing must be taught from a finished specimen of the object to be drawn. Such a specimen must be exhibited and the scholars questioned concerning the details of shape, arrangement of parts, and dimensions, the scholars being allowed to measure the different dimensions as the work proceeds. From the information thus gained the teacher should prepare rough sketches, marking in the dimensions, and from these proceed to prepare a finished working drawing on the lines already laid down. Later, we shall give in detail the method of taking the lesson for the first exercise. This should serve as an illustration, and the principle can be followed in all future exercises, the teacher varying the detail of the lesson as the scholars acquire more knowledge and skill. Later, the scholars should take a model, analyse it for themselves, make their own rough working sketches, and then proceed to execute the finished drawing. The preparation of rough working sketches introduces facilities for practice in freehand work.

Drawing Tools Necessary.—Each scholar should be provided with the following drawing instruments.

RULE.—This should have on one edge inches subdivided into sixteenths throughout the entire length, whilst on the other edge it should be subdivided into millimeters. Rules should be manufactured from the finest-quality boxwood, which has been thoroughly well seasoned and is straight grained. Cheap rules are usually made of inferior-quality boxwood, and quickly warp, thus making them useless for the production of accurate work.

SET SQUARES.—The most suitable are those framed from well-seasoned pearwood. The vulcanite set squares, whilst retaining their shape well, are apt to accumulate dirt upon the surface, which is easily transferred to the paper, thus making the drawings dirty.

Each scholar will require two, i.e. one 6 in., 45°, and one 7 in., 60°.

PENCILS.—Each scholar should be provided with two pencils, an H or H H, for drawing, and an H B or F, for writing.

Fig 9

For mechanical drawing it is usual to sharpen the pencil to a "chisel" point, as shown in accompanying figure, thereby ensuring a clean sharp line. Where young children are concerned there is a danger of such points being used "broadside" on. It is often advisable, therefore, to adopt the conical point in such cases, reserving the use of the "chisel edge" for senior classes only.

RUBBERS.—In the early stages it is not wise to distribute rubber to each scholar. Should an error occur the scholars should call the attention of the teacher to the mistake, who should make the necessary erasure. This plan serves to engender habits of carefulness and attention, and the teacher early finds out who are his weak scholars, and can give them any special attention required. Later, when correct habits have been formed, the scholars can be relied upon to execute their own erasures.

COMPASSES.—These should be about 6 in. long. They should be strong and well jointed. It is advisable that they be of such a pattern that ordinary-sized pencils may be used. The smaller special compass pencils are too apt to break, particularly where, as is often the case, the same compasses have to be used for both drawing and marking on wood.

It is essential that the needle point be kept perfectly sharp. The compass is retained in position by means of the sharp point just gripping the surface of the paper. Blunt points will not grip the surface, and the scholar has perforce to drive the point of his compass into the paper, thus making an unsightly hole, which is a grave error.

The pencil point should be kept sharp, a "chisel edge" may be used with safety in this case.

DRAWING BOARDS AND T-SQUARES.—For senior classes all scholars should be provided with suitable drawing boards and T-squares.

The best drawing boards are those made of American yellow pine, grooved on the back and provided with hardwood ledges, the ledges being fixed by means of screws working in slotted brass plates, thus allowing for expansion and contraction without the danger of splitting or alteration of shape.

The T-squares should be of pearwood or mahogany. Those with taper blades screwed to the stock are best, the taper giving a larger surface of contact with the stock, thus affording better fixing, and reducing the tendency for the angle to become altered should the instrument be carelessly handled.

The most suitable size of drawing board and T-square for manual-training purposes is the "half-imperial".

Method of Using the Drawing Instruments: THE RULE.—By the

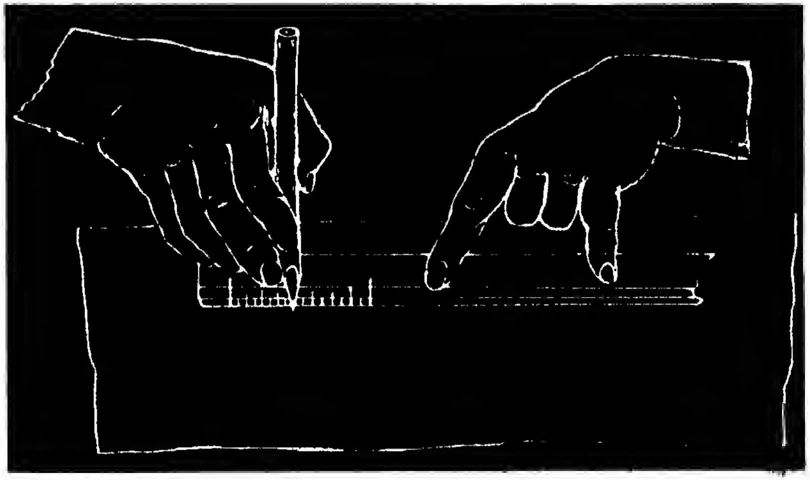

Fig. 10

time the scholars reach the standard of admission to the woodwork class they should have received some training in the use and manipulation of the rule and the principles of measuring. Should the scholars have received no such instruction previously, it will be necessary to explain the division marks on the rule, dealing first with the English standard—the yard—and its subdivisions, and later with the metric standard—the metre—and its subdivisions.

Where the scholars have not previously taken a course of simple mechanical drawing it is advisable that they use drawing books with rules and set squares rather than proceed at once to the use of the drawing board

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and T-square. The use of the rule and set square as here described serves as a very valuable hand training in itself, and helps to engender habits of attention, carefulness, and accuracy; later, drawing boards and T-squares may be introduced.

Thus, in this section of the work the rule serves the dual purpose of measuring and drawing horizontal lines, i.e. those lines extending lengthwise of the paper. All perpendicular lines, i.e. those at right angles to the horizontal lines, are drawn with the aid of the set squares, as explained later.

Fig. 11

When marking dimensions the rule should be held with the first and little fingers of the left hand, the head occupying a position immediately above the position of the mark to be made. The pencil should be held upright, and the necessary mark made by just touching the paper with the point of the pencil. (See fig. 10.)

USING THE SET SQUARES.—As already explained, the set squares are used for enabling us to draw perpendicular lines. They are also useful for enabling lines to be drawn parallel to any given oblique line, and for constructing angles such as those found in the set squares themselves, or which can be obtained by combinations of those angles.

ERECTING PERPENDICULARS.—Having marked the position of the perpendicular, the ruler should be arranged along the horizontal base line and held with the first and little fingers as already described. This serves as a foundation edge along which the set square can be moved. The set square is then slid into position by the right hand. Having carefully ad-

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justed the position of the set square, it is held firmly in [illegible] means of the two middle fingers of the left hand, and the line [illegible] indicated in fig. 11.

Oblique Lines.—When it is necessary to draw a number of lines parallel to any given oblique line, the work can conveniently be accomplished by first placing one edge of the set square, as AB in fig. 12, to the given line MN, then adjusting the ruler to one of the adjacent edges of the set square, as BC. By sliding the set square along the edge of the ruler indicated by the arrow, any number of parallel lines can be drawn.

Fig. 12

Obtaining Various Angles.—The angles usually found in set squares are 90°, 45°, 60°, 30°. It is possible to obtain other angles by combinations of those already given, as will be seen in fig. 13, which shows the method of obtaining angles of 105°, 75°, and 15°.

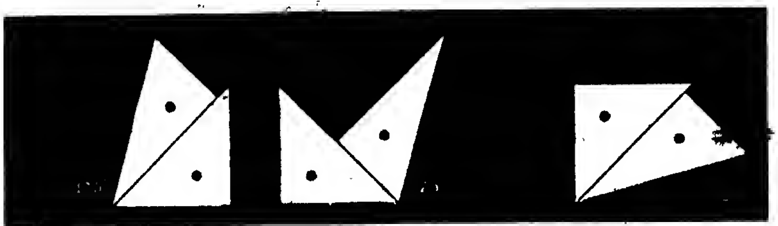

Fig. 13

Method of Setting the Compass.—When compasses have to be used they should first be opened to a distance greater than the required radius, and carefully set by a closing process.

Using the Compasses.—They should be held at the top by means of the thumb and first finger of the right hand (as shown in fig. 14). Held in this way the compass can be swept round the entire circle in either

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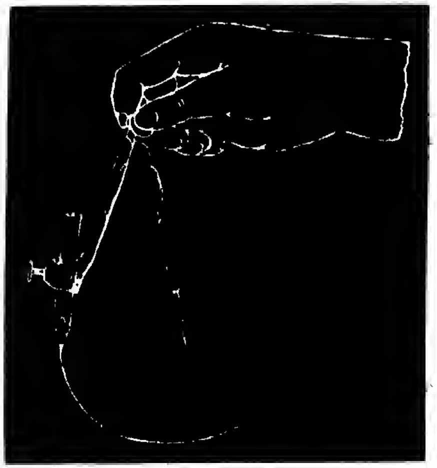

Fig. 14

direction without changing the position of the hand. The compass should slope slightly in the direction of advance. Many draughtsmen now advocate the use of the left hand for compass work, thus to some extent relieving the right hand and also enabling it to retain its hold on the pencil in readiness for further use—a doubtful advantage, though it is recommended as a time-saving arrangement.

USING DRAWING BOARDS AND T-SQUARES.—One great drawback connected with the use of drawing boards and T-squares in manual-training centres arises from the fact that it is seldom possible to complete a drawing in one lesson. The drawings have, therefore, to be removed from the boards at the close of each lesson, in order that the boards may be used by other scholars. This plan has many disadvantages. Once the paper is arranged on the board it should not be removed until the drawing is completed. For this reason it is recommended that the use of drawing boards be reserved for senior scholars only.

Fig. 15

ADJUSTING THE PAPER.—When fixing the paper to the board, care must be taken to ensure that the long edges are at right angles to the working edge

NOTES

of the board. This is done by first loosely fixing the top left corner of the paper in position by means of a pin, as at A in figure, and then regulating the edge of the paper by means of the T-square. When in the correct position the top right-hand corner may be pinned to the board. The paper should be drawn as tight as possible and the remaining corners pinned (fig. 15).

The best method of fixing the paper to the drawing board is to first slightly damp the under surface of the paper in order that it may be stretched, then to glue all the outer edges to the board. When dry it will

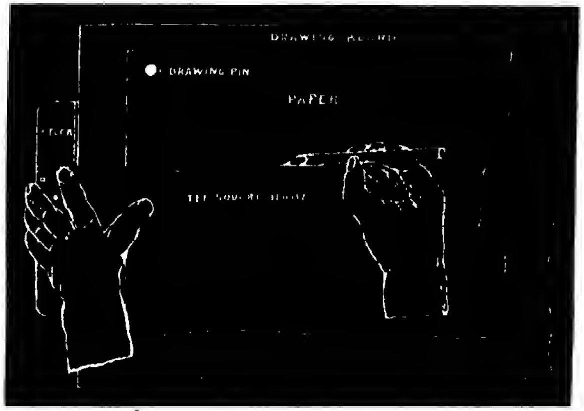

Fig. 16

be found that the paper is exceedingly tight, and lies evenly on the board; the absence of pins is a great advantage. Whilst this is the best method it will easily be seen that it could not conveniently be adopted for manual-training classes.

USING THE T-SQUARE.—The T-square is manipulated by means of the left hand and always from the left edge of the board. The stock should be kept tight against the edge of the board. By sliding the T-square up and down the board it is possible to draw parallel horizontal lines in any desired position (fig. 16). As already explained, perpendicular and oblique lines should be drawn by the aid of the set square.

USE OF INDIARUBBER.—If the drawings are carefully executed, rubbers are seldom required. They should be lightly used and always in one direc-

tion. Heavy rubbing or rubbing backward and forward damages the surface skin of the paper and spoils the drawing.

PLOTTING OUT AND LINING IN.—All work should be carefully plotted out by means of exceedingly fine lines. When the details are finished all unnecessary lines should be erased and the drawing finished by going carefully over all lines and making a clear firm fine line.

When necessary to show hidden details this should be done by means of dotted lines. The following are the systems of lines adopted for mechanical drawing (fig. 17).

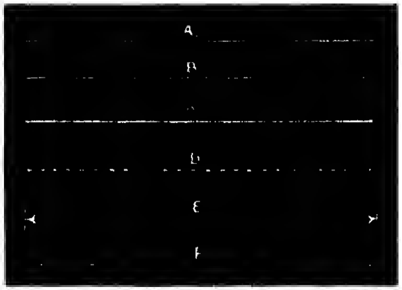

Fig. 17

TYPES OF LINES TO BE ADOPTED.—

A. Plotting out.

B. For representing edges in light.

C. For representing edges in shadow.

D. Hidden details and projectors.

E. Dimension lines.

F. Centre lines.

Writing.—All drawings should be fully detailed. These details should be written, not lettered. Lettering requires considerable time, and unless time permits of its being carefully executed it had better be left undone. It is better that manual-training scholars should be made to write all the necessary detail, leaving printing for the technical scholars. All writing should be carefully executed.

CHAPTER V

Principles of Projection

Orthographic Projection.—Most of the drawings prepared in the manual-training classroom consist of plans, elevations, and sections when necessary. The preparation of the drawings involves a knowledge of the principles of orthographic projection. It is not advisable to enter into an elaborate explanation of these principles with beginners. At the outset they should

be taught on the principle that they are preparing a picture or view of various surfaces of the particular model to be made, such pictures being sufficient to enable them to obtain an idea of the shape and arrangements of the various parts, and also to obtain the dimensions of any portion of the work. This method will be demonstrated in the examples on page 46 and onwards.

The Dihedral Angles.—When considering orthographic projection it is always assumed that the object to be projected stands in one of the angles formed by two planes which intersect each other at right angles, as in fig. 18. The planes are considered to be infinite, i.e. unlimited in area. It will be seen that each angle is formed by the intersection of the faces of two planes, hence the term "dihedral", which means "two-faced". The angles are numbered respectively 1, 2, 3, 4, as shown in fig. 18. Simple projection treats of points, lines, planes, or solids in the first dihedral angle. All problems treated in this work will therefore be confined to this angle, and for further details concerning the other angles readers must refer to advanced works on geometry.

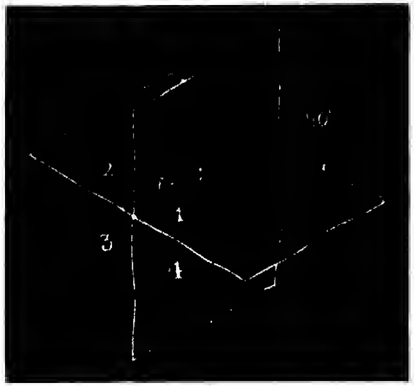

Fig. 18

Analysis of the Model.—All models consist of a number of surfaces. The adjacent surfaces intersect in edges; the edges intersect at the corners.

In the drawing all edges are represented by lines, the lines having definite lengths according to the edges which they represent. The extremities of the lines are points, which points thus represent the corners of the object. Reasoning thus we have first to consider the projections of points in the dihedral angle, and once the principle is understood little difficulty should be experienced in connection with the lines, planes, and solids.

Projections of Points.—A model of the dihedral angle should be prepared by hinging two pieces of wood or cardboard together, preferably with blackened surfaces in order that chalks may be used for marking the surfaces (fig. 19).

Each plane must be named as in sketch shown in fig. 19, the joint X X representing the ground line. Such a model will enable the various examples to be presented to the class in a form which they will readily understand.

Example.—Take a fairly large white marble or bead to illustrate the point. Place it in various positions, as indicated in fig. 20, using knitting needles or pieces of wood to illustrate the projectors to the planes.

When the point A rests on the H.P., move the marble in various positions, calling attention to the fact that whilst the marble remains on the H.P. the picture of it on the V.P. must always rest on the line of intersection between the two planes. The position of the point will be defined by stating that it rests upon the H.P. and at a certain distance from the V.P.

Fig. 19

Explain.—(*a*) The picture projected upon the H.P. is called a PLAN.

(*b*) The picture projected upon the V.P. is called an ELEVATION.

(*c*) The pictures are obtained by carrying projectors from all points in the object to the various planes, such projectors being always at right angles to the plane on which the picture is being drawn, this surface being known as the PLANE OF PROJECTION.

Give further demonstrations of the various positions which a point may occupy, and question the class meanwhile concerning its position relative to the planes. Call upon one of the scholars to come forward and hold the point in any given position.

(*a*) On the H.P. 3 in. from V.P.
(*b*) On the V.P. 4 in. from H.P.
(*c*) 4 in. from H.P. and V.P.
(*d*) 3 in. from H.P. and 2 in. from V.P.

NOTE.—Fig. 20 shows the point in these positions.

When the scholar has placed the point in the desired position, question the class concerning the position which the plan and elevation will occupy with respect to the line of intersection between the planes. Having

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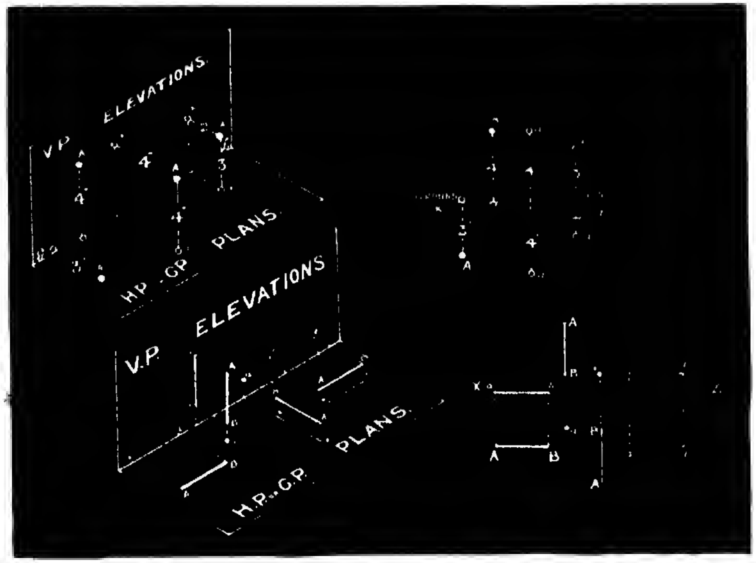
mastered these positions and marked the plan and elevation upon their respective planes, turn the V.P. down about its hinge line so that it lies flat or in the same plane as the H.P. Draw a chalk line along the hinge line.

The teacher must now explain that when preparing plans and elevations of objects the draughtsman has to take an imaginary position above the

Fig. 20 Fig. 21



Figs. 20-21 (above) Fig. 22 Fig. 23

object, in order that he may look down upon it and make a drawing of what is seen or known to be there in order to obtain a plan. For the elevation he must take an imaginary position in front of the object, and imagine that all points are projected back at right angles on the vertical plane. If other views, such as end or side elevations, are required, then the position occupied must be such that it will yield the desired view.

When drawing an object it would be inconvenient to have the paper folded like the model used for illustrating the principle. The draughtsman

therefore leaves his paper flat and draws a line across it which he calls the "ground line", and which represents the hinge line which is marked in chalk upon the model, and separates the two planes, i.e. V.P. and H.P. The picture below the line is called the "plan", whilst the picture above the line is called the "elevation". It is often usual not to draw this ground line but simply to imagine its position, for the following reason. When drawing objects it is usual to imagine that they rest upon the H.P., and as already seen, under these conditions the "elevation" will rest upon the "ground line". The lower line of the "elevation" therefore occupies a position in keeping with such "ground line". Any space between the plan and elevation may be taken to represent the distance of the object from the V.P. These points can be further dealt with as the positions of lines, planes, and solids are demonstrated. Fig. 21 shows the orthographic projections of the points shown on the previous figure.

Projection of Lines.—When the teacher is satisfied that the scholars have a fair working idea concerning the projections of a point in space, the next step is to treat a line in a similar manner. Use a pencil or piece of stick, preferably painted white, for the demonstration, and with a small white ball at each end to represent terminal points. Have ready the model of the dihedral angle as before. Lay the line on the H.P.; question class concerning the position of the points, i.e. their distance from the V.P., their distance from one another, the position which the elevation will occupy. Lift the line vertically upwards and again question. Vary the position, and question. Hold the line in an inclined position, and call attention to the foreshortening of either the plan or elevation according to the particular plane to which the line happens to be inclined.

NOTE.—The question of lines inclined to both planes of projection, whilst being casually mentioned, should not be in any way exhaustively treated at this stage. The necessary construction required to obtain the true length of such lines, involving as it does the introduction of a third plane, can follow when the more simple principles have been mastered. Fig. 22 shows the model with a line in the following positions.

(*a*) 3 in. from V.P. and resting on H.P.

(*b*) 2 in. from V.P., perpendicular to H.P., and 1 in. above it.

(*c*) Perpendicular to V.P., 1 in. above H.P., and 2 in. in front of V.P.

(*d*) Parallel to H.P. and V.P., 4 in. in front of V.P., and 1 in. above H.P.

Fig. 23 shows the projections of such lines as they would appear on a sheet of paper.

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Fig. 24 shows the model with lines variously inclined to the planes of projection.

(*a*) Line A B inclined 45° to V.P., parallel to H.P. and 1 in. above it. A 2 in. in front of V.P.

(*b*) Line A B inclined 45° to H.P., parallel to V.P. and 3 in. in front of V.P. A is 1 in. above H.P.

Fig. 25 shows the projections of lines occupying these positions as they would appear on paper.

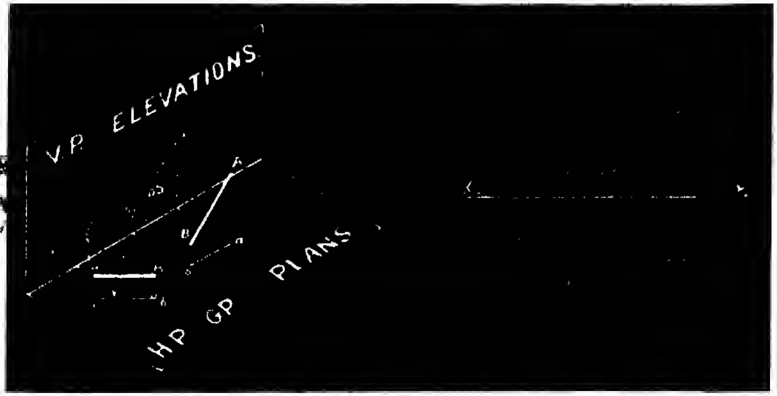

Fig. 24 Fig. 25

When dealing with the projections of lines, first deal only with the points representing their extremities, and, having settled the projections of these, the line joining the points may then be drawn.

Having dealt with the projections of lines, surfaces may now be treated in a similar manner. Cut out several pieces of paper rectangular in form. Call attention to the fact that all edges must be represented by lines, and that the edges terminating in corners will be represented by points, the position of which will depend upon the lengths of the various edges of the model. Proceed to deal with the projection of each corner individually as for projecting points; having determined their position on each plane the necessary lines representing the edges of the figure may be drawn. These principles will be readily understood by reference to fig. 26.

At A is shown a rectangular plane 3 in. by 2 in. It is parallel to and

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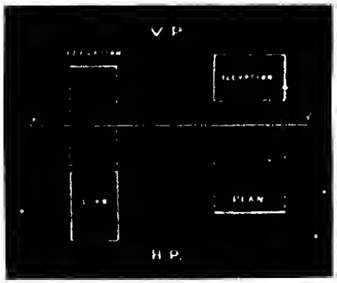
2½ in. above the H.P., whilst the back edge is parallel to and 2 in. from the V.P. At B is shown a rectangular plane 3 in. by 2 in. It is parallel to and 4 in. from the V.P.; the lower edge is parallel to and 1 in. above the H.P.

A B
Fig. 26

Other positions should be demonstrated, and the scholars questioned concerning the position of the plan and elevation relative to the ground line.

The planes of projection should be turned down so as to lie in the same plane, and the relative position of each view pointed out, as was done in previous examples. These are shown in fig. 27. It now only remains to deal with the projection of a solid body. For this purpose take a rectangular slab of wood about 5 in. by 2 in. by 1 in. Attention should be called to the shape of each surface, the nature of the edges, and their relative positions.



A B
Fig 27

Holding the model in position in the dihedral angle, as indicated in fig. 28, proceed to deal with the projection of the plan as was done when projecting the rectangular planes in the last example. Next deal with the elevation; having projected the points representing the corners, join the points, thus completing the two views required. These details will readily be understood by reference to fig. 28, which shows the block in the following position: A large face parallel to and 2 in. above the H.P.; the edge parallel to and 5 in in front of the V.P.

Fig. 29 shows the orthographic projection of the solid in the described position.

Other forms may be dealt with, also examples in which the object rests upon the H.P. One example should serve to complete this section.

Fig. 30 shows the projection of a rectangular box made out of $\frac{1}{2}$-in. material. In order to show the construction of the box an end elevation is necessary. For this purpose a second vertical plane must be introduced, standing at right angles to the first. Reference to the figure and a

Fig. 28 Fig. 29

knowledge of the preceding principles should enable the scholars readily to understand the requirements of this case. Call attention to the fact that if the box be lowered upon the H.P. it will in no way change the details of the plan or elevation. The plan will occupy the same position, but the elevation, whilst remaining the same in detail, will move down upon the ground line, and, as already explained, it is usual to assume that objects occupy such a position on the H.P. when dealing with their projection for manual-training purposes.

Isometric Projection.—The main difficulty which beginners experience when dealing with the orthographic projections of solids is that of forming a mental picture of the solid as it really appears from the various views

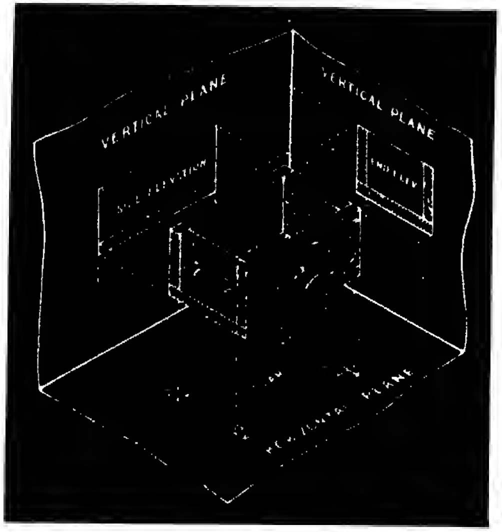


Fig. 80

presented. This difficulty is to a great extent overcome by the use of isometric projection, which, whilst it is a true projection of the object, yet combines in one view three faces of the object, thus giving a pictorial effect to the projection.

Such projections often have a distorted appearance, because the edges do not appear to vanish as in model or perspective drawing. It is only necessary to state that an isometric projection is a true projection just as in the case of orthographic projection; therefore edges which are parallel in the object will be represented by parallel lines on the plane of projection. This will be better understood when referring later to the principles underlying such projection.

Fig. 81

It will further be seen that this form of projection lends itself more readily to rectilinear objects, though objects having curved outlines can also be similarly projected, as will be seen from the examples which are given.

The basis of this form of projection lies in the fact that any object having a rectangular form is so arranged that three of its edges forming a solid right-angled corner are equally inclined to the plane of projection. All points in the object are then projected on to the plane of projection, just as in the case of orthographic projecting. Hence

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when the drawing is complete a view is obtained of three surfaces of the object. Such a view, whilst being pictorial in character, does not give a true representation of the shape of each surface of the object as in an orthographic projection.

Another difficulty arises from the fact that, owing to the edges being inclined to the plane of projection, there is considerable foreshortening of the real lengths, and if the projections are to be true to scale it becomes necessary to ascertain the correct ratio existing between the actual length and the foreshortened length.

This ratio will be found to be as $\sqrt{3}$ to $\sqrt{2}$, which ratio is shown in fig. 31. If natural lengths be marked along the edge A B, and perpendiculars let fall on A C, these lengths are the isometric equivalents. Hence an isometric scale can be constructed. The use of such a scale is unnecessary for manual-training purposes, for it will readily be seen that any natural scale can be used provided always that the scale is stated, and that scale used for ascertaining dimensions when the object drawn is to be made. For further details concerning the proof of the above ratio, readers are referred to advanced works on geometry.

Isometric Projection of Model

Front Elevation of the Model

Fig. 32

Teaching the Principles.—For this purpose the teacher should provide himself with a model as shown in fig. 32. It consists of a wood base

having a glass screen let into one end. Behind this screen, and supported on a knitting needle, is a cube. It will be seen that the knitting needle passes through the diagonal of the solid; hence, if the needle stands perpendicular to the plane (wood base), the edges of the cube will be equally inclined to that plane. Having prepared the model in this manner, a projection can now be made on the glass screen, the lines being drawn with a piece of soap. First mark the position of point A, then proceed to project corners B D E and join to A. Next project the corners F H C, joining the various points as shown, thus completing the projection of the edges. A complete view of the cube is thus obtained, showing three of its faces. The edges A B, A D, and A E each bound similar angles, i.e. right angles, and these angles, as already explained, are equally inclined to the plane of projection. Therefore their projections are equal; that is, the angle contained at the centre by each pair is equal. Now the sum of these angles must be 360°; therefore the angles, being equal, each must contain 120°, and these angles are constant for all rectangular bodies.

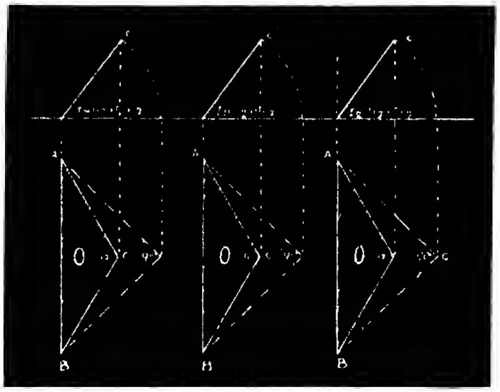

Fig. 33


Fig. 34

NOTE.—Fig. 33 shows a method of demonstrating to the class the fact that equal angles equally inclined have equal projections. Take three set squares and incline them equally, make projections as shown, and measure the contained angles. Mastery of this principle affords the key to all isometric projection.

The three edges meeting in the centre point, and enclosing angles of

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120°, are known as the "isometric axes". The point of intersection is called the "regulating point", shown in fig. 34.

If a line be drawn at right angles to any axis, then the remaining axes must make angles of 30° with such a line. This fact proves of great convenience, for it enables a base line to be drawn, as in fig. 35, on which can be marked the R.P., and the axes drawn as shown by the aid of a 30° set square. Along these axes the main dimensions of the solid are measured, and the view completed by drawing lines parallel to the respective axes.

Fig 35

Objects which are not rectangular in form must have an imaginary rectangular framework constructed about them, in order that the necessary

Fig. 36 Fig. 37

dimensions may be determined in the isometric view. It must be clearly borne in mind that all dimensions must be measured either on the axes or

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on lines parallel to the axes. This will be readily understood by reference to the examples which follow.

Fig. 36 shows a rectangular prism having its faces equally inclined to both

Fig. 38

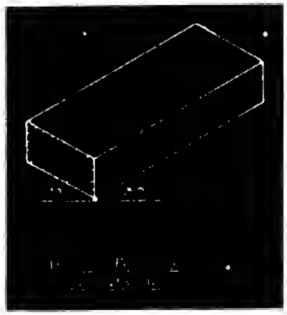

Fig. 39

planes of projection. Fig. 37, which is an orthographic projection of the solid so placed, shows that each view is an isometric projection.

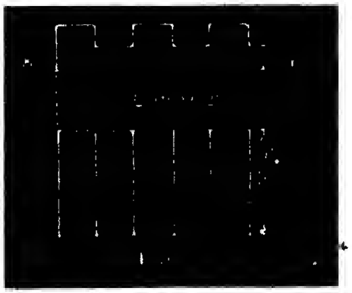

Fig. 40

Fig. 41

Fig. 38 shows the orthographic projections of a rectangular solid, and fig. 39 its isometric projections.

Fig. 40 is a portion of the first exercise in orthographic projection, and fig. 41 its isometric projection.

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Fig. 42 is the orthographic projection of the work in Course I, Exercise II (p. 246), whilst fig. 43 is its isometric projection, and shows the method to employ when dealing with the removal of corners.

Fig. 42

Figs. 44 and 45 afford a further example in treating of objects the corners of which have been removed.

Fig. 46 is the orthographic projection of one end of the keyboard, and fig. 47 its isometric projection. Such an example must be treated as if it were rectangular, then the corners removed, finally placing on the chamfer lines.

Fig. 43

NOTE.—In the foregoing exercises the holes have not been taken into consideration; being small, they do not lend themselves so readily for teaching the principles involved as do the succeeding exercises.

Figs. 48 and 49 indicate the method of treating prismatic and cylindrical bodies. In order to obtain the isometric view of the circle it must be enclosed in a square and the diagonals and diameters drawn. Through the point of intersection made by the diagonals and the circle

Fig. 44

Fig. 45

draw lines parallel to the side of the square; thus when the square and other lines are drawn in isometric projection eight points in the curve are determined, and the projection of the circle can be traced through these points.

NOTE.—The isometric projection of a circle is an ellipse.

Fig. 46

Fig. 47

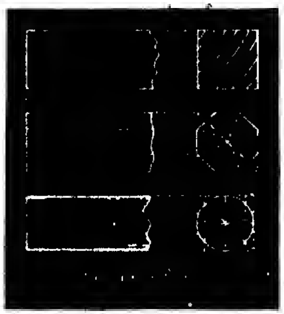

Fig. 48

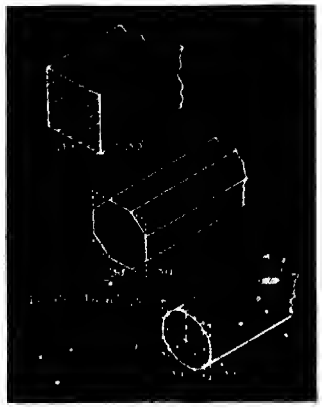

Fig. 49

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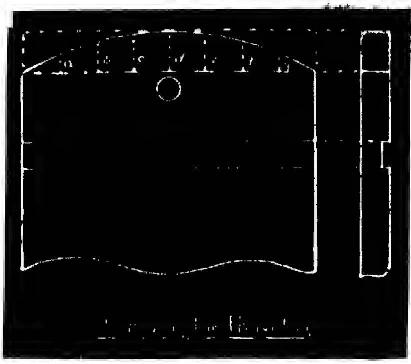

Fig. 50

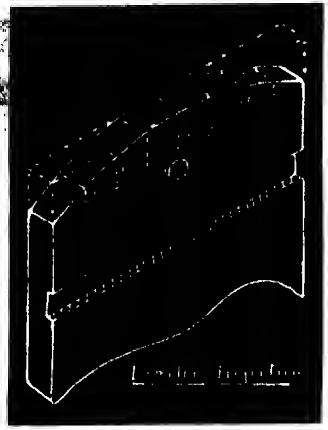

Fig. 51

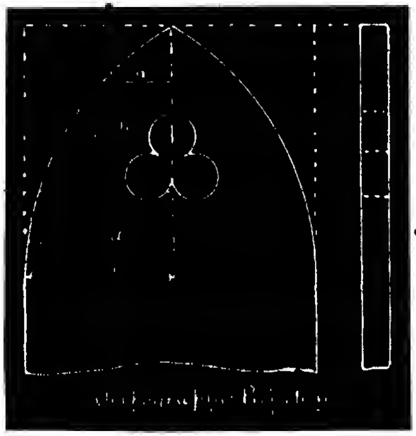

Fig. 52

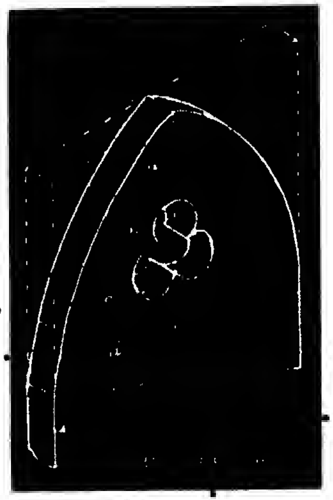

Fig. 53

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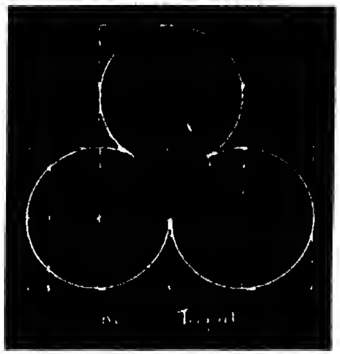

Fig. 54

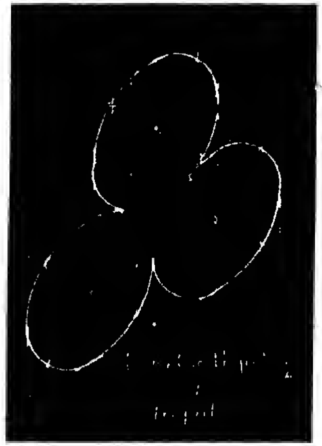

Fig. 55

Figs. 50 and 51 show the method of dealing with curved surfaces. *a*, *b*, *c*, *d*, *e*, *f*, *g* in fig. 50 are ordinates. These are drawn in the same relative position in the isometric view, and the lengths of each transferred from the orthographic projection to the isometric projection and the curve traced through the points.

Fig. 56

Figs. 52 and 53 are further examples of the use of ordinates.

Figs. 54 and 55 show the method of treating the trefoil in 52–53.

Fig. 56 represents the isometric projection of the end of the roller shown in fig. 57. Though complicated in appearance, all the principles involved have already been dealt with. When dealing with such an exercise it is advisable to first proceed with the rectangular frame forming the back, afterwards adding details of the support and roller.

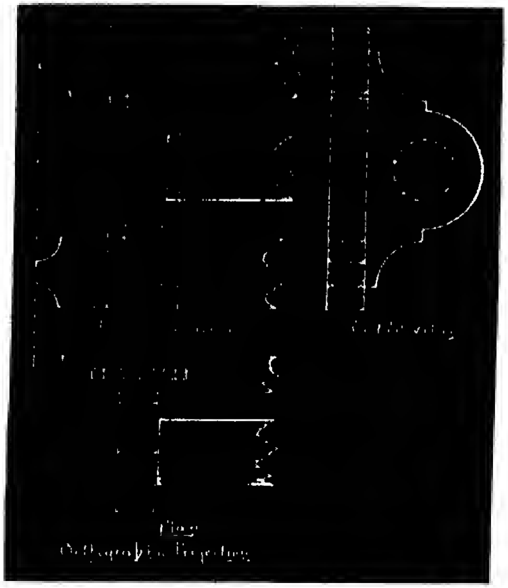

Fig. 57

CHAPTER VI

Growth of Trees

NOTE.—The subject has been treated after the manner of "Notes of a Lesson with Blackboard Summary". This method has been adopted to give some idea of the method of treating the subject, and teachers will select only so much of the matter and blackboard summary as will serve for any one lesson. This note also applies to following chapters, dealing with: Seasoning; Shrinkage; Transverse Section of a Tree; Chemical Structure, &c.

Before we can thoroughly understand the nature of the wood obtained

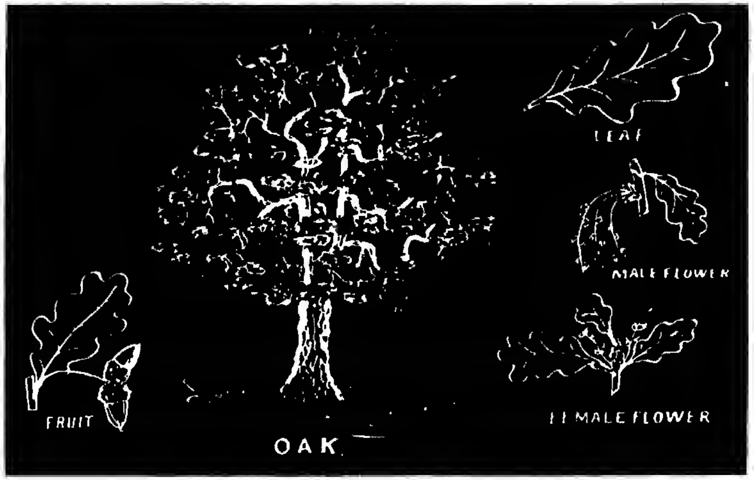

Fig. 58

from trees it is necessary that we should know something about the process of growth.

Fig. 59

Parts of Growing Trees.—You are all familiar with growing trees. Can you name the different parts? These will be given in varying order but can be arranged as follows: (*a*) root, (*b*) stem, (*c*) branches, (*d*) leaves, (*e*) flowers, (*f*) fruit.

Let us start from the fruit, and let us take an acorn for our example.

Germination.—[Exhibit an acorn.] What kind of tree yields acorns? If this acorn were placed in the ground, under favourable conditions, what do you expect would happen? What do you think this seed needs to enable it to grow? Soil, water, warmth. Having planted it, what would you expect to find after a few days or weeks? Where does the little shoot come from? Let us open this acorn and see what it contains.

NOTE.—If the acorn be soaked for a time in water, and germination started, it will aid the lesson.

NOTES

Embryo Root and Leaves.—Notice that the seed splits into halves. Point to embryo leaves and root. *Explain*: What they are; what they will develop into; where they get their food supply from.

Use of Cotyledons.—*Explain*: The seed lobes, "dicotyledons", contain the necessary food material to enable the plant under favourable conditions to throw up its leaf shoot and throw down its rootlets (fig. 61, A and B). Having done this, the seed lobes are of no further use, and each part of the miniature tree performs its own duty.

Here, then, is a young oak tree. What a tiny mite! Is it possible that it can ever become the "Monarch of the Forest", as oak trees are often called? Let us

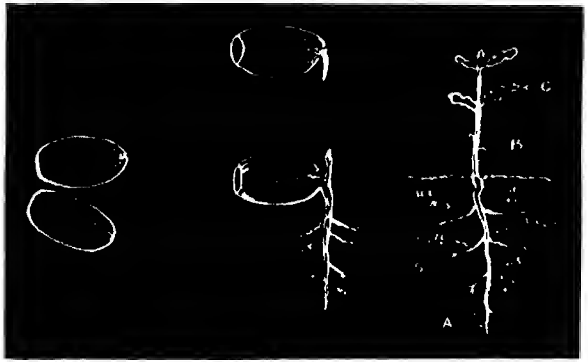

Fig 60 Fig. 61 Fig 62

try to find out how this happens. [Make the accompanying sketches (figs. 61, 62) on the blackboard.]

Roots and their Functions.—Examine the sketch on the blackboard. What is the name of the part which is buried in the ground? What is the upright part B called? What is C? What happens to the plants in your garden if no rain falls and you forget to water them? What do you do? Will it do to place the water at or near the root, and not over the top? What happens to the leaves when you water the roots? How does the water get from the roots to the leaves? You have many times pulled up a growing plant, and no doubt you have noticed how the roots have spread out. Why do they spread so far? Do you think the plant could live on water alone? When you wish to make a plant thrive, what do you do to the soil? What do farmers do to their fields? Why? But how can the manure get from the soil into the tree?

Root Food in Soluble Form.—What happens to sugar if you pour water upon it? Well, instead of saying it melts, we say that it dissolves. When we have

made such a sugary syrup we say that the sugar is in a soluble form. Now this is the form in which plants take most of their food. The water which falls as rain, or is poured on the earth, passes down, and as it does so "dissolves" various mineral substances which are present in the earth. This mixture forms the food of the tree. The roots take in this "liquid food", and it is passed from the roots up the stem and out to the leaves.

Ascending Sap changes its Form.—Though the roots have taken in this "food material", it is not yet ready for building up the wood of the tree. It is very much like the flour, butter, sugar, eggs, currants, &c., which your mother has in the larder ready for making a cake, but whilst in this form it is "not cake". It has to be specially treated first. Let us find out how the food ingredients in the tree are treated.

Evaporation from Leaves.—The leaves, as you know, are exposed to the sun, and we have already observed what happens when no rain falls or the plants are not watered. What is taking place? Where is the water coming from? What causes the water to flow up the tree? "Evaporation." That is partly the reason; in later lessons it will be explained how the roots actually help by "forcing" the water up; and, further, it is yet a problem how the water passes to the top of the highest trees. You boys might try to discover the reason and so become famous.

Leaves Breathe.—Notice what happens when this leaf is placed in water. Where did those bubbles of air come from? Now, strange as it seems, these leaves "breathe" very much as we do. There are small openings in the leaves which serve as mouths, and they take in air.

Carbon extracted from the Air.—A substance, called carbon, is extracted from this air, which mixes with the other food material that has risen from the roots. Owing to the influence of the sun the whole mixture is now converted into suitable food for the plant. Just as when mother has mixed all the ingredients and baked the cake it is ready to be eaten.

Carbon Insoluble in Water.—Carbon is not soluble in water, hence none passes to the tree by means of the roots. All the carbon the tree requires it must obtain from the atmosphere by means of the leaves. You will be surprised to learn that practically the whole of the solid part of a tree consists of carbon.

Experiment.—A very useful experiment can here be carried out, should time permit. If not, prepare it beforehand and briefly explain how you obtained the specimen.

Take two pieces of wood of uniform size, weigh them, and note weights. Thoroughly dry one, weigh again, and note decrease due to loss of water. Place dry piece in a retort, and drive off all gases and reduce specimen to *carbon*. Weigh again, and note loss due to decomposition, loss of gases and essential oils, &c.

Compare weight and bulk of carbon with previous specimen. If this experiment is carefully performed, and the distillate collected as the experiment proceeds, the three stages can be preserved in bottles, as: (*a*) a

piece of wood; (*b*) the water and essential oils; (*c*) the residue, mainly *carbon*.

Distribution of Prepared Food.—Most of the water which served the purpose of dissolving the mineral substances in the earth, and carrying them up the tree, now evaporates, and the food is ready for distribution to build up the body of the tree. But how is this done? The changes which take place do so mainly in the upper surface of each leaf, the part upon which the sun shines. The food material then passes to the under side of the leaf, travels along certain channels down the leaf stalk, down the branches and stems, passing to all parts, including the roots, feeding the tree in its course and enabling it to grow.

Cambium Layer.—But where is it growing; does it merely become taller? Does it not also become bigger? How is this? Let us examine this little branch. Scrape away some of the bark. Do you notice this slimy layer? Well, that is what we will call "the growing layer"; its real name is "cambium layer"; it is composed of living cells which, when growth is active, are constantly splitting up and forming more cells, some of which are added to the woody inner parts of the tree, and some to the outer parts, which most of you know as the bark. You will see that this growing layer is situated between the "wood" and the "bark".

Bast Fibres.—How is the food to reach this layer? The food travels to all parts of the tree by means of a layer of "fibres" composing the inner parts of the bark, called the "bast fibres".

Period of Growth.—Are leaves always to be found on the tree? When do they begin to burst out? When do they drop off? Do you think that growth is actively taking place when there are no leaves on the tree? Is the tree "dead" just because there are no leaves on it? What is the tree doing during this leafless period? What do you suppose will have happened to the tree during the period between the time when the leaves first formed and when they faded and dropped off? Yes, every part of our tree has been covered with a layer of wood. What will happen to the tree during the next season's growth? Hence you see, year by year, a new layer of wood is formed over every part of the tree. The tree grows taller, the branches become longer and bigger, and the roots also become larger and spread farther under the soil.

Ascent of Sap.—We have followed the path of the returning sap, but we have not yet found out which part of the tree it rises through. You have cut a young branch from a tree. Was the wood dry? Where did the water come from which was in the branch? Where was it going? Well, that illustrates what is taking place in the main body of the tree. The "sap" rises up through the wood composing the main trunk of the tree, and returns, as we have already seen, by means of the inner layer of bark.

Sapwood and Heartwood.—Here is a section of a much older tree; you will notice that there is a difference in colour between the inner and the outer part of the tree. You do not understand this. When the tree is young the sap rises through the whole of the wood composing the stem, but as the tree becomes older and larger, the sap rises mainly through the outer portion of the stem, this lighter part in our specimen, hence this outer part is called the "sapwood", whilst the inner part, forming the heart, is called the "heartwood". If you test them with

your finger nail you will discover something. What is it? Why the change? Let us find out.

Heartwood and Supporting Column.—Do you often hear of trees being blown down when the wind blows? You have been out in a wind storm and know that it is difficult to keep your feet; now think of some of the large trees you know of. Why are they not blown down? Why are they not broken off? Yes, it is because they are strong, and nature has so beautifully arranged their method of growth that they get the greatest amount of strength just where they are most likely to break. Where is this? What is the size of the stem at the top? Now this central column of "heartwood" serves merely to strengthen the tree and enable it to carry the huge head of foliage which we all so much love to see, and which is necessary to enable it to provide enough material to supply all its many parts.

Heartwood not Essential to Growth.—Would the tree die if the heartwood were destroyed? Have you never seen a "hollow tree" which is continuing to grow? What is likely to happen to such a tree when the wind storms come? You probably have heard a person say, when speaking of a tree that has been blown down: "It was rotten at the heart". Why is this?

Period of Life.—Trees, like human beings, have a definite period of life, and when they have reached a certain age they begin to fade and die. They may take years to die.

The cambium becomes less active, the heart commences to decay, and the tree is likely to be attacked by many diseases, just as human beings are.

Time for Felling.—If the tree is to be used for commercial purposes it must be cut down as it is reaching its prime, and before it commences to decay.

Some trees are fully grown in fifty years, others in a hundred, whilst some go on for many hundreds, as is the case with our Monarch of the Forest—the Oak.

BLACKBOARD SUMMARY

GROWTH OF TREES

Parts of Tree.—Root. Stem. Branches. Leaves. Flowers. Fruit.

Germination.—Warmth and moisture cause seeds to throw out tiny roots and growing buds. (Root = Radicles. Bud = Plumule.)

Cotyledons.—The seed lobes (Dicotyledons = two lobes) contain food supply for germinating root and stem.

Function of Roots.—Gather necessary food for the tree. Food in a liquid form.

The Leaves.—Sap rises to the leaves. Sun causes evaporation. Absorb air. Extract carbon from air. Chemical changes take place. Sap elements converted into food for the tree. Main bulk of tree consists of carbon.

Distribution of Prepared Food.—Returns from leaves to twigs and branches, passes to stem and roots, supplying all parts with food.

Cambium Layer.—Layer of living cells immediately beneath bark. Cells split up and form wood cells and bark cells.

Bast Fibres.—Fibres comprising portion of inner bark. Sap carriers.

Period of Growth.—Commences in *Spring.* Most active during *Summer.* *Activity* ceases in Autumn. *Winter* a period of rest.
Ascending Sap.—Rises through the "Sapwood" = outer part of tree.
Sapwood and Heartwood.—Sapwood = outer portion—fairly soft. Heartwood = inner portion—harder than sapwood.
Heartwood.—Supports tree in soil. Supports heavy load of branches and foliage.
Period of Life.—Varies in different trees.
Felling.—If required for commercial purposes they must be cut as they arrive at maturity.

CHAPTER VII

The Transverse Section of a Tree

Required for the Lesson.—Transverse section of oak.

The Transverse Cut.—Exhibit a transverse section of a tree to the class—preferably one in which the characteristic parts are clearly defined, as in oak and pine. Question concerning kind of material. From what is wood obtained? How has the tree been cut in order to yield a piece like this? (referring to transverse section). Such a cut is called a "transverse" cut. Explain the meaning of the word "transverse". Let us examine this section carefully, and as we proceed endeavour to find and name the various parts.

Annual Rings.—Probably all of you have seen and examined the stump of a tree after the tree has been cut down. Most of you have endeavoured to count the marks which you saw on the cut portion in order to find out something about the tree. What did you count? What did you endeavour to find out by counting those rings? If you can tell the age of a tree by counting the rings, what does each ring represent with regard to the growth of the tree? What do we call events which take place regularly every year, such as sports, &c.? Seeing that these rings are formed regularly every year, what can they be called? "Annual rings." Are these rings true circles? Examine them closely; are they of uniform thickness? At which part of the tree are the rings thickest? Where are the thin rings situated?

Cause of Visibility of Rings.—How is it that the rings can be seen at all? Can you see any rings on this? [Hold up a clean sheet of white paper. Make some rings on it with a piece of chalk.] Can you see these rings clearly? Why? Suppose rings were drawn on the blackboard with pencil; would they be distinct? Why? Now, probably you can explain why it is that the annual rings on a transverse section are so distinct.

Composition of Rings.—Examine the individual rings more minutely. Is the substance of any particular ring uniform in colour? How does the portion of a

ring which is nearest the centre of a tree differ from the outer portion of the ring? Look still more closely at this piece. Can you see these small holes? In which portion of the ring are they situated? What are such small holes called? Refer to other substances which are porous, i.e. sponge, bread, chalk. Test each part of the ring with your finger nail in order to discover which is the harder portion. What have you discovered? Where is the softer portion of each ring situated? We have now discovered three points of difference between the inner and the outer portion of each ring. Name these points. "Lighter in colour, more porous, much softer."

Spring and Autumn Wood.—At which period of the year do we find the trees budding forth and commencing to grow? When did the tree commence to form the inner portion of each of these annual rings? [Explain.] In consequence of this the inner portion of each ring is called the "springwood". When do the trees lose their leaves and cease growing for the year? What might the outer portion of each ring be called? "Autumnwood."

Heartwood and Sapwood.—Examine the colour of the whole surface as a mass. What do you notice? Where is the darkest portion situated? Which do you think is the older portion of the tree, the dark or the light portion? Test each portion in a manner similar to that in which you tested the parts of the annual rings. What have you discovered? Where is the harder portion situated? Pour a little water over each part, and observe what happens. Where has the water gone? Which part absorbed the water most quickly? Can you explain why this is? "More porous and softer." [Explain: The inner portion is called the "heartwood" whilst the outer portion is called the "sapwood".] Which do you consider to be the better portion of a tree from a commercial point of view? Why? What objection do you see to the use of the sapwood for constructional purposes?

Bark and its Use.—You are all familiar with the name of this rough outer portion which surrounds the section. What is it called? We will endeavour to find a use for it. Where is the living growing portion of a tree? What name did we give to this layer in a previous lesson? What would happen to this layer during frosty weather if it were unprotected? Can you think of any other sources of danger to this layer? Lead up to attack by insects and cattle. Can you now suggest one use for the bark? Did we not also discover in a previous lesson that the elaborated sap passed from the leaves to all parts of the tree by means of the "bast fibres" forming part of the bark. You see, therefore, the bark plays another important part. [Describe the services rendered by the bark of trees.]

Growth of Bark.—When the tree from which this section was cut was no thicker than a pencil it was covered with bark. You can observe that it is still covered with bark. How does the bark grow in order to keep pace with the growth of the tree? Where must the growing portion of the bark be situated? Hence you see that the cambium layer, whilst it adds a layer of wood to the tree, is also adding a new layer of bark. How is it that we cannot find as many layers of bark as we have discovered annual rings? Notice the rough bark, and how easily layers split off.

Medullary Rays.—There is something which we have not yet mentioned, viz. if the specimen is one of oak, or one in which the "medullary rays"

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are visible. Call attention of class to the lines radiating from the centre to the bark. If a young stem of a plant be cut through, what do you find occupying the middle portion?

Explain: "Pith or Medulla".

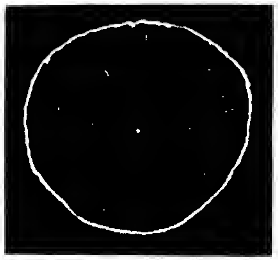
The reason for the pith being less prominent in larger sections is that the wood as it develops exerts an enormous pressure on the pith, and in many cases squeezes it out of existence, so that only a point is visible. If the pressure be not so great, the pith, though much compressed, still remains visible. Show examples, i.e. boxwood, nil.; pine, a little. The lines run (radiate) from the pith outwards in all directions. What do we call the rays of light which radiate from the sun? What can we call these lines (rays) which radiate from the "medulla or pith"? "Medullary rays."

BLACKBOARD NOTES

Annual Rings:

(*a*) *Springwood.*—Inner part of ring—Light in colour—porous—soft.

(*b*) *Autumnwood.*—Outer part of ring—Darker in colour—dense—hard.



Sapwood.—Light outer portion of tree—Soft—porous—inferior.

Heartwood.—Dark inner portion—the part used for commercial purposes.

Bark.—Surrounds tree—Protects cambium layer—Distributes food to tree.

Medullary Rays.—Appear as lines radiating from centre.

Pith or Medulla.—Small speck at or near the centre.

CHAPTER VIII

Seasoning Timber

Required for the Lesson.—A few laths of wood.

Growing Tree contains Sap.—[Refer to trees growing vigorously and covered with leaves.] What happens if you cut twigs from such trees and do not put the cut end in water? Why does it wither? Why do not all the leaves on a tree wither on

a hot day? Where does the tree obtain the moisture which prevents the foliage from withering? How does the moisture pass from the earth to the leaves? What is this moisture in the tree called? "Sap." You already know that the sap rises up through that portion of the tree which we have called the sapwood.

Condition of Wood when Cut.—Suppose a tree is felled for the purpose of cutting it into planks for constructional purposes. What would be the condition of the wood? "Wet" or "damp".

Evaporation or Shrinkage.—You are very fond of "juicy apples" and "juicy oranges". What would happen to your apple or orange if you happened to place it away on a shelf for a considerable time? What happens to a piece of bread if left exposed for a considerable time? "Becomes dry." Will the apple, orange, or piece of bread retain its full size? What happens to it? What do we say of a thing which becomes smaller in this manner? "It shrinks." What is it reasonable to suppose will happen to the planks of wood cut from trees which contain moisture?

Necessity for Seasoning.—Suppose a plank of wood had been cut from a tree, and whilst in a wet condition was used to make some piece of framing, i.e. a door. What would happen to all the parts of the door? What would happen to the joints? Would you consider such a door a good one? What must first be done to all timber before it can safely be used for constructional purposes? [Explain that this process of drying is called "seasoning".] What is really being dried out of the wood whilst it is being seasoned? "Sap." We may, therefore, define "seasoning" as a process by means of which the sap is removed from the wood.

Different Methods of Seasoning.—Probably you are able to describe various ways by which we could dry this sap out of timber. How are clothes dried on washing day? What actually causes them to dry when placed in the open? Would they dry if it were a damp day? What is the condition of the atmosphere on such days? How are the clothes dried on such days as these? What is the difference between the two methods? Explain "natural" in the case of drying in the open air; "artificial" in the case of drying by the fire or similar means. Explain that similar methods are adopted for drying timber, i.e. "seasoning".

Natural Seasoning.—In most cases the planks are stacked in the open air in such a manner that the atmosphere can get freely to all sides of the planks. These stacks may lie under a roof, or if not under a roof the uppermost planks are laid in a sloping position, and are generally somewhat longer than the pieces composing the stack. What is the object of the roof or sloping planks? What method of drying would you call this? How can the pieces be laid so that the atmosphere can get at all sides of the plank? Call upon a scholar to lay the laths of wood in similar position; if unable to do so, the teacher should stack the laths in order to illustrate the method. Refer to stacks of timber in local timber yards.

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Artificial Seasoning.—Suppose we wish to dry the timber very quickly, will it do to place it out in the open air? Why not? Can you suggest a method of drying it more quickly?

Refer again to the drying of clothes on a wet day. What kind of room or building would be necessary in which to stack the timber? How can such a room be heated? How are larger halls and public buildings usually heated?

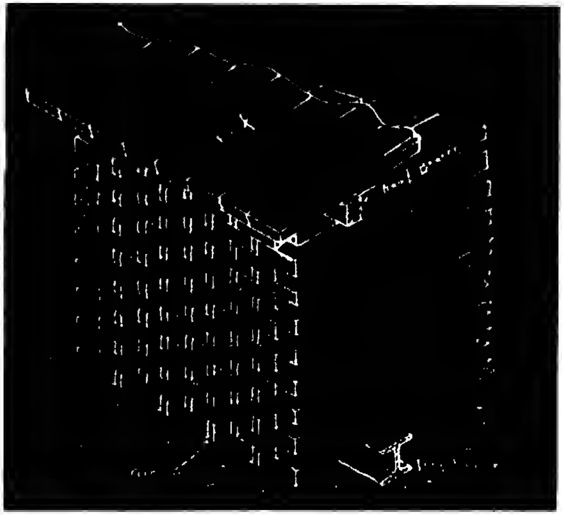

Fig 64

Do you think it better to have an open fireplace or steam pipes ranged round the walls? Which method will be most likely to keep the temperature uniform? Which method will best distribute the heat throughout the room or chamber? Which would constitute the best method of heating a room in which a lot of timber was stacked for the purpose of drying? Call attention to the necessity for constant attention in the case of open fires, and the waste of heat attending such a method. Will articles dry in a room which is moist with steam? Will any moisture be given off from timber as it is being dried? What arrangements must be made for getting rid of this moisture? Call

attention to necessity for ventilating such a chamber. What would you call such a method of drying timber—natural or artificial? Which process dries the timber more quickly?

Comparison.—Which do you consider the more expensive method? Explain that the natural method is adopted for seasoning thick timber, and timber which is to be applied to more common purposes, such as building, &c. The artificial method, which is called "hot-air process" is usually applied to special wood and thin boards which are intended to be used for special purposes, such as furniture, office fittings, and the more important portions of the interior of first-class buildings.

BLACKBOARD NOTES

SEASONING TIMBER

Reasons for.—To dry out the sap.
Sap.—"Moisture"—Evaporates.
Two methods of doing so:—

(*a*) Natural.
(*b*) Artificial.

Natural.—Timber stacked in open air—So arranged that air can circulate freely round each plank—Protected from rain by roof or sloping planks—Takes a long time—Cheap—Adopted for timber to be used for ordinary purposes.
Artificial.—Timber stacked in special chambers heated by steam pipes—Ventilated to allow moisture to pass away—Much quicker—More costly—Applied to timber to be used for special purposes.
Other Methods.—Running stream—Hot water—Smoke drying.

CHAPTER IX

Shrinkage of Timber

Required for the Lesson.—

Tranverse section of oak or beech.
Tranverse section of pine or poplar.
Sections of timber variously cut.

We have seen that when timber dries it shrinks. It is necessary now to consider how this shrinkage affects the plank.

Examination of Transverse Section.—*Exhibit transverse section of a tree*, preferably one split through shrinkage.

What is the shape of this section? Call upon a scholar to point out its natural centre. What have we called that part? "Pith." What are these marks called? [Teacher pointing to "annual rings".] What has caused this "split"? Where is the timber that originally filled this opening (split)? Why did not the circumference approach the centre uniformly, thus preventing splitting?

Reason of Splitting.—The cause of splitting is a difficult question and we will try to discover the reason.

Most of you have placed a biscuit in your tea and noticed that it became swollen in all directions. The diameter became greater. Suppose you were to dry the biscuit again, would it split as this piece of wood has done? No, it would not split, because all the component parts of the biscuit are free to move towards the centre, and, the biscuit being thin, all parts dry at a uniform rate. Examine this piece of wood to see if you can discover anything likely to keep the outer rim from approaching the centre? What are those line-like markings called to which you are pointing? "Medullary rays." You have already had explained that these are layers of cells arranged in a direction at right angles to the cells and fibres composing the general mass of the wood. You will notice that the medullary rays are arranged like spokes in a wheel. What purpose do the spokes in a wheel serve? Can the outer part of the log approach the centre when these medullary rays are present? Do you suppose their presence will prevent the moisture evaporating? Shrinkage must take place, and the rim is prevented from approaching the centre—What must happen? This is known as "tangential shrinkage".

Experiment.—It will serve as a good illustration to take a cylinder of wood and stretch a rubber ring round it; cut through the ring and the scholars will see how the ring contracts in a circumferential direction, whereas, if the diameter of the stretched ring be compared with this ring in its normal condition it will be seen that the shrinkage has taken place in a radial direction.

Tangential Shrinkage.—You will now understand that the shrinkage takes place at right angles to the medullary rays, this is called "tangential shrinkage".

Medullary Rays Absent.—Suppose no medullary rays happen to be present in the log, how do you suppose it will shrink? Yes, you would expect it to approach the centre without splitting, but we must examine this more in detail. What is the condition of the log when cut? Which part of the log is likely to contain most moisture? Where is the sapwood situated? Which will shrink most, the heartwood or sapwood? Why is this?

If a log be laid in the open air, as for "Natural Seasoning" (see page 60), which portion is likely to dry first? Will the inside or heart of the log be likely to dry

at the same rate? Hence the outside is shrinking whilst the inside remains full size. What must take place then? What would tend to prevent this splitting? "Slow drying."

Planes of Cleavage.—We have seen that, whether the medullary rays be present or not—unless something be done—splitting is sure to take place. Can we say

Fig. 65

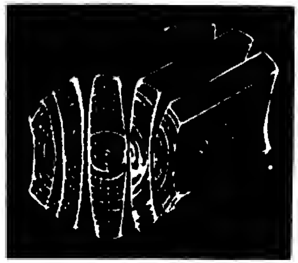

Fig. 65a

where it will split? This will depend on the drying and the weak places—"planes of cleavage"—in the log. What direction will the splitting take? Yes, it will follow the direction of the fibres, and if these be arranged in a spiral manner, as they are in many trees, it is easy to see that the "split" will take a spiral turn round the log. How will this affect the planks when the log is cut up?

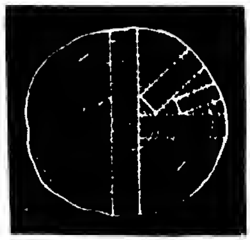

Fig. 66

Treatment of Log.—Can you suggest a method of treating the log when it is known that sooner or later it has to be cut into planks? Yes, the log should be cut up. Does this prevent the shrinkage? How will each plank shrink?

Effect of Shrinkage.—The teacher should make sketches showing different methods of cutting the log, and explain the effect of shrinkage in each case.

In fig. 65 the cuts are all parallel to a diameter, and the effect of the shrinkage on each plank is indicated in fig. 65a.

Does the middle plank become curved to the same extent as the outer planks? Why is this? Which side of each plank is convex? Why is this? The specimen indicated contains strong medullary rays. Suppose the log had contained no medullary rays, would the planks have curved to the same extent? Can you explain why they would be less curved?

Radial Cutting.—Could the log be so cut as to enable all planks to remain

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flat? In what direction would such cuts have to be made? Make a sketch of this as shown in fig. 66.

These cuts are called "radial cuts". Can all the "wedge-shaped pieces" be used? What would you say of such a method of cutting timber? Though wasteful, it has often to be done for timber to be used in better-class work, particularly

Fig. 67

with oak, because in addition to preventing the planks twisting it shows the pretty figuring "silver grain--medullary rays" to the greatest extent. [Exhibit specimen if possible.]

Comparison of Section.—Make sketches of the ends of logs, as in fig. 67, and call upon a scholar to indicate on them, by dotted lines, the effect of shrinkage.

Exhibit certain specimens of wood, and see if they conform to this law. Examine the jack planes; these afford valuable examples for the necessity of studying the particular arrangement of the grain with a view to ensuring "rectangular" expansion and contraction.

BLACKBOARD NOTES

All timber shrinks while drying.
Circumference tends to approach pith.
Often prevented by presence of medullary rays.
Greatest amount of shrinkage takes place in a tangential direction.
Medullary rays cause shrinkage to affect shape of cut timber.
If logs be uncut they split with a V-shaped opening.
Splits follow weakest lines of cleavage—often spiral.
When cut parallel to diameter the pieces curve, and have the convex surfaces towards the pith.
When cut in a "radial" direction the medullary rays are parallel to the surface, and planks remain flat.
Radial cutting—Wasteful and expensive—Adopted for better-class work—particularly oak.

CHAPTER X

Chemical Structure of Wood and Products formed by Chemical Changes and Decomposition

Structure of Wood.—A thorough analysis of the chemical structure of a piece of wood would carry us far beyond the range of manual training, yet the subject must not be allowed to pass unnoticed.

We have seen that different kinds of wood vary in density. Is this due to varying chemical composition or arrangement of the constituent parts?

We have seen that trees increase in size by growth at the extremities of all their parts and by the subdivision of certain cells (merismatic = dividing by the formation of internal partitions), forming a layer over the whole of the woody portion of the tree (cambium layer), which layer is protected by the bark. We have further seen that the leaves of trees perform a kind of breathing operation, thus taking in air, from which carbon is extracted; also that the roots take in various mineral substances in solution.

The production of the actual food material is due to chemical changes which take place in the leaves of the tree in the presence of light, air, and warmth. The various elements absorbed by the tree are in this way largely converted into glucose (a form of sugar) in the leaves, from which it is passed to all parts of the tree, and is there modified for the purpose of building up the woody tissue. The various functions observed are all necessary to a complete performance of these chemical changes.

The density, we shall see, is not affected by these chemical changes, but is due entirely to the particular arrangements of the component parts of the wood, i.e. cells, vessels, and fibres.

It has been found by experiment that the chief substances which plants need for building up their various tissues are as follows:—

Carbon (C), oxygen (O), nitrogen (N), hydrogen (H), sulphur (S). These elements are essential for the development of protoplasm (protoplasm = a transparent substance apparently structureless, and similar in character to the white of an egg; it constitutes the basis of living matter in all plant structures) and the substance cellulose, of which practically the whole of the woody matter consists. They are therefore known as the organic elements.

(*a*) Carbon forms one of the chief elements in the structure of wood,

entering as it does into the composition of every part of the woody tissues. If a piece of wood be burned in a closed vessel, watery vapour and gases are given off, and when these cease to be given off there remains a mass of black substance known as "charcoal"—which is practically pure carbon.

Experiment.—Take a piece of wood about 6 in. by 1 in. by 1 in., and note carefully its weight. Place it in a desiccating tube and expose the tube to the flame of a spirit lamp or gas jet, and when all the vapours and gases have been given off remove contents of tube and weigh again. Compare weight after desiccation with former weight, and it will be found that the carbon weighs approximately one-half the weight of the piece of wood taken for the experiment. Repeat the experiment with various kinds of wood, and it will be found that this ratio is fairly constant, thus establishing the fact that for all woody matter practically one-half by weight is carbon.

(*b*) Oxygen.—The supply of oxygen is mainly derived from the water taken in by the plant (water consisting of a compound of two gases, hydrogen 2 parts, and oxygen 1 part,—volume), also from the carbonic acid gas which is found as an impurity in the atmosphere, and which passes into the leaves during the breathing process. The gas is composed of carbon 1 part and oxygen 2 parts (CO_2).

Further supplies of oxygen are obtained from the various metallic salts containing oxygen, during the chemical changes which take place in these during their conversion into food elements for the tree.

(*c*) Hydrogen.—This substance is obtained chiefly from the water in the plant, which we have seen has the composition: hydrogen 2 parts, oxygen 1 part. Further supplies are obtained from the various metallic salts containing hydrogen, during the various chemical changes which take place.

Experiment.—Take a desiccating tube and place in it some chips of wood, or a piece as before mentioned; seal the open end with clay, through which the stem of a clay tobacco pipe passes to the interior. Now place the apparatus in the flame of a spirit lamp. Very soon a stream of watery vapour (steam) will be seen to issue from the open end of the stem. Place a lighted match to this, and the light is quickly extinguished. Later it will be seen that thick smoke issues from the stem. Again place a lighted match to the open end, and again it will be found that the flame is extinguished. The escaping substance is a mixture of steam and smoke. (Smoke = unconsumed particles of carbon.) When the thick smoke ceases to be given off, if the hand be placed near the open end it will be found that a hot jet of gas is rushing out of the pipe. Place the lighted match to this, and it at once lights

up, burning with a bright flame. This burning substance is chiefly hydrogen gas, but contains small quantities of carbon, hence the yellowness of the flame. When the flame ceases it will be found that all escape from the tube has ceased; that is, all the volatile substances and gases have been driven off from the wood, and again nothing but charcoal (carbon) remains within the vessel.

Note.—This experiment can be performed with an ordinary clay pipe, but the desiccating tube is better, as a larger volume of wood can be treated.

(*d*) SULPHUR.—This element is essential to the formation of all protoplasmic and albuminoid substances. It is derived from the various sulphates, which are salts of sulphuric acid. (Sulphuric acid = H_2SO_4.) A form of lime impregnated with sulphur, and known as gypsum, constitutes a valuable source of supply (Calcium sulphate = $CaSO_4$).

(*e*) NITROGEN.—This substance is essential to the formation of protoplasmic and albuminoid bodies. It is derived from the various nitrates, which are salts of nitric acid. (Nitric acid = HNO_3.) Trees do not take in the nitrogen existing in an uncombined state in the atmosphere, but derive all their supplies from the various nitrogenous compounds.

(*f*) OTHER ELEMENTS.—Other elements are also found in very small quantities, and whilst these may be regarded as essential in order to enable the various chemical changes to take place, and the plant structure to perform its natural functions, the quantities are so small that they will not be separately treated here. They are as follows:—

Metallic Elements.—Iron (Fe), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na).

Non-metallic Elements.—Silicon (Si), phosphorus (P), chlorine (Cl).

A chemical analysis of a piece of wood shows the approximate composition to be as follows:—

Carbon	51·0
Oxygen	41·5
Hydrogen	6·25
Nitrogen	1·0
Ash	·25
	100·00

The ash contains the various metallic and other elements.

In various specimens of wood it is found that these figures do not vary more than approximately 1 per cent. Hence it will be seen that the varying

density of wood is not due to varying chemical composition, but owes its variableness to the arrangement of the woody structure.

Experiment.—(*a*) Take a piece of American yellow pine or cedar, and float it in water. It floats because, volume for volume, it is lighter than water.

Next take a similar piece of wood and plane some very thin shavings from the end grain; dry these thoroughly (warm them) and place them in water. The water quickly takes the place of the air, some of which was expelled during the process of warming, and the shavings sink, showing at once that the absolute density of wood is greater than that of water.

(*b*) Take a piece of charcoal and float it in water. Why does it float?

Take a similar piece of charcoal and reduce it to an exceedingly fine powder, and mix it with some water. If allowed to stand it will be found that most of the powder sinks to the bottom. Why? What does this teach us?

Having studied the nature of the elements composing timber, let us now enquire into the nature of some of the products brought about by decomposition, naturally or artificially performed.

Charcoal.—This substance is the residue left after driving off all the watery and gaseous substances contained in the wood. It plays an important part in the arts. It is capable of producing very intense heat when burned in conjunction with oxygen, and is used by goldsmiths.

It is produced in two ways.

(*a*) By slow burning of stacks of timber which have been covered with turf in order to prevent access of air, or—

(*b*) By a process of distillation, the timber being placed in large iron cylinders beneath which a fire is lighted. During the process of distillation many by-products are yielded.

Uses of Charcoal.—For refining sugar. Removes organic matter from water. Absorbs gases readily; useful in sickroom or places where bad smells arise. In the manufacture of gunpowder. Used medicinally for many purposes.

By-products formed during Distillation.—Acetic acid. Wood naphtha. Tar. During the previous experiment, when testing for hydrogen, it was probably noticed that a brown viscid fluid dripped from the stem of the pipe. Th substance is known as "wood tar"—commonly termed "Stockholm tar", b reason of the vast industry carried on at Stockholm in the manufacture of tar from the pine trees. The name "Stockholm tar" is now applied to this substance no matter where the article is manufactured. Stockholm

tar is brown in colour and has a strong pungent odour. It is largely used for preserving wood, and by sailmakers for preserving canvas and ropes.

Pine and Fir Trees.—These all yield a substance known as "turpentine". It is collected from the growing trees by making incisions in the bark and allowing the exuding sap to flow into a vessel. This crude material is distilled, and from it "spirits of turpentine" is obtained; the residue left after distillation is the ordinary resin of commerce.

Canada Balsam is a turpentine from the Balm of Gilead Fir (Abies). It is slightly yellow, transparent, possesses an agreeable odour, and an acrid taste. Used for optical work, and for mounting microscopic specimens.

Resins.—There are many different kinds of resins, some of which are not obtained from the pines and firs. Many of the harder varieties are used in the manufacture of varnish, and some are used for medicinal purposes. The principal forms used for these purposes are: Amber (mineralized form), dragon's blood, storax, scammony, jalap, gamboge, galbanum, lac, dammar, mastic, copal, sandarac.

DAMMAR.—A form of resin yielded by the Amboyna Pine (*Agathis orientalis*) found growing in the Malay Archipelago.

Another species of this tree, the Kauri Pine (*Agathis australis*) yields an inferior variety of dammar. The Kauri Pine is found in New Zealand. Dammar is used in the manufacture of varnish.

COPAL.—The name of several varieties of resin used in the manufacture of varnish. Found also in fossil form in Africa at a depth of 3 or 4 ft. below the surface.

Walnut Trees.—The fruit yields an oil which is largely used on the Continent by artists. It is also used as a food and for lighting purposes, and a dark-brown dye is obtained from the husks. The sap yields a form of sugar.

Oak Trees yield a substance known as gallic acid, the name being derived from the oak galls, which contribute the chief supply. This substance is used for medicinal purposes and in the manufacture of ink.

Maple Trees.—One variety of this tree (*Acer saccharinum*) yields a considerable quantity of sugar. The trees are tapped during the spring, when the sap flows into the incision. The sap thus obtained is evaporated and sugar forms the residue.

Eucalyptus Trees.—These trees are found growing in Australia, and from their leaves a valuable oil is distilled. This oil is largely used for medicinal purposes. One variety of the tree (*Eucalyptus resinifera*) yields a gum which also is used in the preparation of medicines.

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Rosewood (*Dalbergia nigra*).—This tree yields an oil which has a fragrant odour. It is known as "oil of Rhodium." The odour is that of sandalwood and roses mixed, and has peculiar powers of attracting certain animals —horses and rats.

Camphor.—This substance is obtained from the Camphor tree (*Cinnamomum Camphora*) found growing in Japan, China, and Formosa. This tree also grows exceedingly well in South Africa.

The wood is placed in vessels containing water, and covered with straw matting. The water is gradually heated, and the volatilized camphor condenses on the straw matting in the form of crystalline masses. The masses are afterwards purified and the camphor of commerce is produced.

The various products formed by plant structure are due to chemical changes or decomposition of the cellulose forming the cell walls.

CHAPTER XI

Science in Manual Training

Consciously or unconsciously all the exercises which the scholars perform in the manual-training classrooms bristle with scientific problems. Many of the problems are worked through quite unconsciously, and results arrived at without a knowledge of the laws which enable such problems to be solved. Scientific statements are made and facts expressed without stopping to investigate the truth of such statements or examine such facts.

As already explained, the main aim of the manual-training lessons is not alone the production of a number of well-executed models, and the acquirement of so much manual dexterity, but the fact must be borne in mind that it is a "complete" man which is being developed. A man capable of right thought, a man capable of "thought-directed" action. Models may be beautifully executed, the producer may possess wonderful skill or dexterity of hand, yet it is possible that such models and such dexterity have not called forth that mental effort, that thought-directed action, which it should be the aim of the teacher to instil. This can be done only by "pointing the way", by leading the scholars step by step to think and reason before taking definite action. Every line placed on the wood, every cut made with saw or chisel, every blow with hammer or mallet must be *thought-directed.* The

questions: What is this? Why is this? What caused that? What is likely to happen if . . . ?" &c., should be ever to the front during the lessons. It is only in this way that manual training comes to serve its true end, which is to aid in the development of the true man—a man capable of right thought, a man capable of right action, a man capable of thinking and giving concrete expression to his thoughts.

It would not be possible to deal with all the problems which arise during the manual-training lessons, but an endeavour will be made briefly to suggest a few to which teachers might give attention, supplementing these for themselves as occasions arise.

As soon as the scholar enters the classroom he is given a piece of wood; he is told to "measure" it, to "test its weight", and, later, to exert "force" on the saw or chisel in order to produce "work".

Now, what is the piece of wood? What do we mean by "measure"? What is understood by "weight"? What is "force"? What is "work"?

Matter.—In nature we find many substances which can be seen and handled, which can be tasted, or which can be smelt, or which, by means of our senses, we know to exist. Such substances may exist in one of three forms, or may partake of the nature of all three, i.e.:

Here is a piece of stone, a piece of iron, a piece of wood; these we call "solid" substances.

Here is some water, some oil; these we call "liquid" substances.

You can feel the wind blowing upon you though you can neither see nor smell it. You know that we can light our rooms by means of a substance which passes along a pipe, and which, when the tap is turned on, we can smell and light. These substances are gases.

Hence we see that substances exist in various forms as: Solids, liquids, gases.

All such substances which can thus be detected by the senses are known as "matter". We can now say that our piece of wood is a "piece of matter". All wood can be seen and handled, therefore all wood is matter.

You will see that this piece of wood takes up a certain amount of room. This water fills the jar. The gas, we know, fills the pipe. The room, we know, is full of air. We can place the piece of wood in any position, and it neither alters its shape nor does it occupy more space. This then is known as a solid body, and we have ways and means of finding the amount of space (*volume*) which such a body occupies.

The water, as we have seen, fills the jar, but we cannot place the water alone in any position as we did the piece of wood. You know what would happen if we tried. Hence we see that whilst we can find out how much space (volume) a given quantity of water occupies, its form is always changing according to the nature of the vessel containing it. We can form an enormously high column, provided we put sufficient into a tube; but it must have the tubing to keep it in position. We can cover a very large area, provided it be poured out on a smooth flat surface.

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Hence liquids, whilst they have a definite volume, have no definite shape, but take the shape of the vessels which contain them.

What of the gas in the pipe? Turn on the tap for a few seconds and you will quickly smell the gas in all parts of the room. Why? The room is full of gas, we say. How did it manage to fill the whole room?

Gases differ from solids and liquids. A gas occupies no definite space (volume), but will spread itself equally throughout the whole space in which it is, no matter how small the quantity. It certainly takes the shape of the vessel or room containing it, but spreads to all parts, and does not, like water, fill only the lower portion.

Hence we see that gases have neither definite shape nor volume.

Measurement.—Now we can measure all substances, but the method adopted varies according to the nature of the particular material. Every country, too, adopts its own particular "standard". In this country we now use the standards laid down by other countries as well as our own, i.e. the British standard, the Cape standard (in South Africa), and the French standard known as the "Metric System".

We will first deal with the British and metric standards.

Examine a rule and notice the division marks along the edges. What do they represent, and how are they obtained? There are inches on one side and centimetres on the other side. Are all inches alike? Are all centimetres alike? What governs their length?

The British standard of length is known as the "yard" and this has been defined by Act of Parliament to be: "The distance between marks made across golden studs let into the ends of a bronze bar and measured when at a temperature of 62° F.". This is known as the "Imperial standard yard". Several of these bars have been made, and are securely kept in order that all other measures may from time to time be tested by the standard.

Examine a "yard stick" and notice that it is divided into *three* equal parts each of which we call a "foot". Each foot is again divided into *twelve* parts which we call "inches". These may be again subdivided into $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, and so on, or they may be divided into $\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1000}$, &c. Notice the various division marks to the inch on your rules.

The Metric System.—The French also inserted a gold stud at each end of a bronze bar and made a mark across each stud when the temperature was at 40° F. They determined the distance between the marks on the studs by measuring the distance from the equator to the pole along an imaginary line passing through Paris. This distance they divided into *ten million* equal parts which they named "metres". Unfortunately it was found later that they had made a slight mistake in calculating the distance, hence the metric system is after all an arbitrary standard and not a truly fixed national standard.

Having obtained the metre it was divided into $\frac{1}{10}$ths, $\frac{1}{100}$ths, $\frac{1}{1000}$ths, called, respectively: decimetres, centimetres, millimetres.

Examine a rule subdivided according to British and metric standards. On the rules we have two standard systems by means of which to determine the length, breadth, and thickness of any body.

What is the length of your piece of wood? What is the breadth of your piece of wood?

The area of rectangles can be found by multiplying the length by the breadth. We will work the example in both standards. When we wish to find the volume of *cubes* or *brick-like* objects, we can do so by multiplying the product of the length and breadth by the thickness. Find the volume of your piece of wood.

In future we shall know how to find the volume of our various exercises, assuming that they are rectangular in shape. The method for determining the volume of solids which are irregular in shape will be explained later.

Weight.—Here is a piece of wood [take a piece of ebony or other very heavy wood for comparison with the pine or poplar of the exercise] which is exactly the same size as yours, that is, it has the same length, breadth, and thickness, that is, it has the same volume. Take hold of them. What do you notice? A difference in weight. How can we explain this difference in weight, and what is meant by weight?

We know that if a body is let fall it is at once pulled to the earth, and bodies that remain at rest, as, for instance, this piece of wood resting on the table, are pressing downwards on the surface upon which they rest. This pressure is due to the earth's attractive pull, known as "gravity". The earth's pull is uniform on all bodies having equal volumes and containing an equal quantity of matter, and this pull, which we can feel and which demands muscular effort on our part in order to sustain a load, we call the "weight of a body". The weight will vary as we approach or become farther removed from the earth's centre. The weight of a body is only constant, therefore, when weighed always in the same place.

You have compared the weights of the two pieces of wood and found that one is heavier than the other. Why is this, seeing that they are the same size? It is clear that there must be a difference. The difference is that one contains more "matter" than the other, and the amount of matter which a body contains is known as the "mass", and we can compare the masses of given bodies by comparing their weight. On comparing our two specimens of wood we find that one is heavier than the other, then clearly that which is the heavier contains more matter, that is, it has a greater "mass". In order to measure the mass of a body we must have some standard. The British standard is the "pound", it consists of a lump of platinum preserved in the office of the Exchequer.

For purposes of convenience we have subdivisions of the pound (lb.), as ounces, and multiples of the pound, as stone (14 lb.), hundredweight (112 lb.), ton (2240 lb.), and Cape ton (2000 lb.).

The metric standard of mass is the mass of a cubic centimetre of water at a temperature of 4° C.; it is known as the gramme.

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Density.—Referring again to our specimens of wood, we know they possess equal volumes, we also know that one contains more matter than the other, and we say of that which contains most matter that it is more dense. When we wish to compare the density of two or more bodies we must state the quantity of matter contained by a cubic unit of each.

For purposes of comparison we often state the "specific density" of a body. That is, we make a comparison between the mass of unit volume of any substance and the mass of a unit volume of water. Now, water weighs approximately 62·5 lb. per cubic foot, and as it is taken as the unit its specific density is said to be 1. Suppose a body weighs 31·25 lb. per cubic foot, then its specific density is ·5.

Specific Gravity.—If now a comparison be made between the weight of a given volume of any substance and an equal volume of water, this is known as the "specific gravity". This refers to the weight only, whereas specific density referred to the quantity of matter. Here, again, water at a temperature of 60° F. is taken as the unit. The specific gravity of water then is 1. If now we know the specific gravity of a substance we can calculate its weight. The specific gravity of American yellow pine is abont ·5. Hence the weight of 1 cu. ft. of this wood will be found by multiplying 62·5 by ·5 = 31·25 lb.

The specific gravity of—

Beech	=	·8 hence weight	= 62·5 × ·8 =	50 lb. per cubic foot.
Box	=	·9 to 1·03 ,,	= 62·5 × ·9 =	56·25 lb. per cubic foot, or nearly equal to water.
Ebony	=	1·2 hence	= 62·5 × 1·2 =	75 lb. per cubic foot.
Brass	=	8·4 hence	= 62·5 × 8·4 =	525 lb. per cubic foot.
Iron	=	7·7 hence	= 62·5 × 7·7 =	481·25 lb. per cubic foot.
Lead	=	11·4 hence	= 62·5 × 11·4 =	712·5 lb. per cubic foot.

This knowledge can be usefully applied for estimating the approximate weight of bodies that will float in water, for the floating body displaces a volume of water the weight of which equals the weight of the given substance. Suppose, therefore, we take a piece of wood and float it in water, and observe that about two-thirds of its volume is under water, the weight per cubic foot will be two-thirds of 62·5 lb.

This experiment can be tried later with different specimens of wood, and afterwards comparing the actual weight by means of a balance.

Force and Work.—Having considered the nature of our material we

have now to consider the nature of the "work" to be performed, and the agency by means of which it is executed, i.e. *force*.

Before any work can be executed with the various tools you see in the room, muscular effort must be brought to bear upon them. This muscular effort will require to be greater or less according to the nature of the work to be performed.

Before any work can be done with the tools they must be set in motion. This is accomplished by the exertion of muscular effort, and the motion imparted to the tools is the result of the "force" exerted.

A force may be exerted upon a body and yet it is possible that motion may not be produced. This is owing to the fact that the body upon which the force is exerted presses back, "reacts", with a force equal and opposite to the first force, that is, the body acted upon resists motion until the pressure applied is sufficient to overcome the resistance of the body.

Apply a saw to wood and push lightly, i.e. exert a small force, and you will notice that the cohesion of the fibres prevents the saw moving forward. Now increase the pressure, i.e. exert a greater force, and the cohesion of the fibres is overcome and the saw commences to move forward and execute work in cutting the fibres.

Apply a chisel to the piece of wood and press lightly; again we notice that the cohesion of the particles resists the forward motion of the chisel. If now more force be exerted, the cohesion is overcome and the chisel moves forward.

An approximate measure of such forces can be ascertained by means of a spring balance, and it is usual to express such forces in terms of weight, i.e. a force of so many pounds.

In order to thoroughly understand the nature of any force acting on a body we must know—

1. Its magnitude.
2. Its point of application.
3. The direction in which it acts.
4. Whether it is a pushing or pulling force, i.e. its *sense*.

Graphic Representation.—Such forces may be represented by means of lines.

Take the case of a boy pulling with a force of 5 lb. on a string which is attached to a block of wood. This can be shown as follows (fig. 68):—

Line A B represents the magnitude of the force, and is made 5 units

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long, any distance being taken to represent unit force. The point of application will be the centre of the mass C, i.e. its centre of gravity, or that point at which the concentrated forces due to the earth's pull on each particle of the mass is supposed to act.

Fig. 68

The direction of the line indicates the direction of the force, whilst the arrowhead indicates the "sense" of the force. Assuming that the arrowhead pointed in the opposite direction, clearly the force would be a pushing force, and string would not serve to transmit such a force.

Parallelogram of Forces.—Now let us take the case of two boys each pulling on a separate string, the strings being attached to a block of wood

Fig. 69

as before (fig. 69). The boy at A pulls with a force of 4 lb., whilst the boy at B pulls with a force of 6 lb., and let the lines represent the direction in

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which each is pulling. Now it is clear that the block C will move forward under these pulls, but what will be the actual direction of its motion? This can be determined in the following manner.

Plot off each force to scale as indicated in the last example. Then, A C will have a length of 4 units whilst B C will have a length of 6 units. From A draw A D parallel with BC, and from B draw B D parallel with AC, thus completing a parallelogram. If now a diagonal of the parallelogram be drawn, e.g. the line D C, this line represents the direction in which the block will travel, and further, if measured to the same scale as the forces, it will indicate the nature of one force which might be exerted in order to accomplish the work of the two boys. Thus one boy pulling on the block in the direction C D with a force of 8 lb. will produce the same effect as A and B together. This force of 8 lb. is known as the *resultant*.

Further, supposing we have a piece of string at the back of the block C, and, whilst A and B are pulling, another boy picks up the string at the back and commences pulling with a force equal to D C but in the opposite direction, as indicated in the figure, the effect will be that this pull will just balance the combined pulls of A and B. Such a force is known as the *equilibrant*.

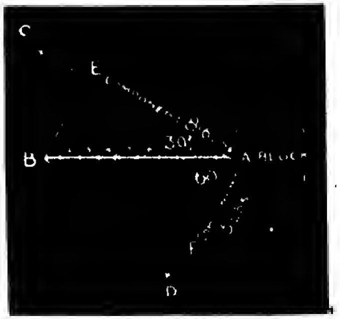

Fig. 70

Resolution of Forces.—We have seen that we can substitute one force acting at D for the forces exerted by A and B. This force is called the "resultant", and is determined by completing a parallelogram about the forces; then clearly if one force acts on a body that force can be resolved into two forces varying in magnitude according as the angle between them and the magnitude of either force varies.

Example.—A force of 10 lb. acts along the line A B (fig. 70) in the direction indicated, and we wish to indicate the magnitude of forces acting along A C at an angle of 30° to A B and along A D which makes an angle of 60° with A B. We have only to proceed as in the former example and from B draw B E parallel to A D, also from B draw B F parallel to A C. If now A E and A F be measured to the same scale as A B the number of

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units in each will represent the magnitude of each force, and these forces are known as the "components".

Now let us examine the saw and the chisel and see if we can apply this knowledge. You will observe that the handle of the saw is inclined to the line of the teeth. Why is this? It is clear that, when we are sawing, the saw has really to move in two directions, forward and downward. But how is this to be accomplished in view of the fact that we exert only one force on the saw? We shall understand this better if we make a diagram (fig. 71). M N represents the handle of the saw, which is inclined at 60° to the line of the teeth; A represents the direction of the force applied to the handle, and is at right angles to M N: B and C represent the direction of the rectangular components the magnitude of which we desire to find. Assuming the force exerted at A to be 12 lb., we can now proceed as follows:—

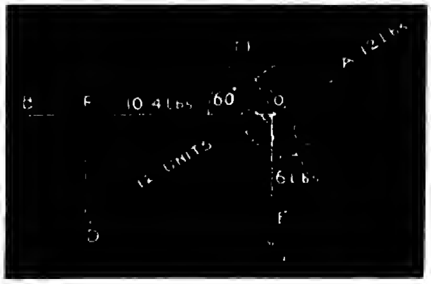

Fig. 71

Produce A O to D, making O D = 12 units of force. Draw D E parallel to B O and from D draw D F parallel to C O. If now O E and O F be measured to the same scale as D O, the number of units in F O represents the magnitude of the forward force due to the pressure exerted at A. Similarly O E represents the magnitude of the downward force on the saw due to the force exerted at A. It will be found that O E will be 6 lb. whilst O F will be approximately 10·4 lb.

Work a similar example as applied to the panel saw.

Now let us ascertain what happens when the chisel is applied to a piece of wood. One forward force is exerted on the handle of the chisel. This has not only to drive the chisel forward, but it has further to overcome the cohesion of the particles and lift out the waste. A diagram will explain the nature of the work to be done. We have seen that the cutting edge of the chisel is formed by the intersection of two plane surfaces mutually inclined at an angle of 35°. Further, we have seen that all action produces a reaction, and these reactions are at right angles to the surface acting. Thus, in the

case of a chisel the "face" acts downwards in the direction of B, whilst the bevelled surface N acts upwards in the direction of C (fig. 72). The muscular force applied to the handle acts along the axis of the chisel, as shown by the line A. Suppose the force A to be 12 lb., what is the magnitude of forces B and C? These can be determined by construction of a parallelogram having sides parallel to C and B, and a diagonal equal in magnitude and direction to force A. These forces are represented in the accompanying figure (fig. 73). Where AO equals the force of 12 lb. to scale, AC is inclined to AO at an angle of 55°, and AB is at right angles to AO. If now OE be drawn parallel to AC, and OF be drawn parallel to AB, the number of units in AE will represent the magnitude of each of the forces B and C. It will therefore be seen that the lifting force of the inclined surface due to the force exerted on the handle will be 21·7 lb. It will further be seen that by reducing the angle of inclination between the faces forming the cutting edge the greater becomes the angle OAC, and consequently the greater becomes the magnitude of the force AE; but whilst the cutting action is thereby increased, it must be borne in mind that every decrease in this angle is tending to weaken the chisel.

Fig. 72

Fig. 73

Further examples in the application of the parallelogram of forces will be found in the use of planes and gouges.

Find by experiment the approximate force exerted on the handle of a jack plane, and determine the rectangular components.

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Having determined the magnitude of the horizontal force acting on the jack plane, determine the direct lifting force due to the inclination of the cutting iron.

Determine experimentally the force applied to the handle of a firmer gouge when making a fluted groove. What will be the direct lifting force of the blade, assuming the gouge to be inclined at an angle of 40°? (Neglecting the resistance due to the curved face of the blade.)

Mechanical Devices.—Practically all the tools we use are so constructed that they embody and admit of the application of some simple mechanical device for enabling the user to gain a "mechanical advantage"; that is, through the agency of the particular tool a small force is multiplied, and thus acts with a greater force than that exerted by the user.

Levers.—One of the most important of these devices is that known as the lever. When you have to raise a very heavy load, you take a rigid bar of wood or iron and place one end of it underneath the load; then you place a stone or solid block under the bar, and begin pressing on the free end. Should the load be exceedingly heavy, and you are unable to lift the load with the bar first chosen, you go in search of a "longer bar". Now, that bar which you used was a *lever*, and the block which you placed beneath it is called a *fulcrum*. The word *fulcrum* means a "prop" or "support". It is the point at which the lever is supported, and about which the lever turns. The word *lever* means "to raise". It is applied to any rigid bar turning on the fulcrum, and used to overcome a resistance (called the *weight*) encountered at one part of the bar, by means of a force (called the *power*) applied at another part of the bar.

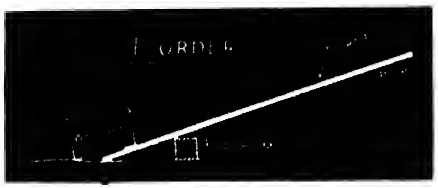

Fig. 74

You will notice that the bar is divided into two parts by the fulcrum. These are called the *arms*. The arm supporting the load is called the *weight arm*, whilst that on which the force or power is exerted is known as the *power arm*.

Levers are arranged in one of three groups, known as orders, which vary according to the position of the fulcrum.

The illustrations will serve to show the relative position in each order.

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Lever of the First Order.—Here it is seen that the fulcrum is situated between the weight and the power.

Lever of the Second Order.—In this order the fulcrum is at one end, and the weight is situated between the fulcrum and the power.

Example.—Pushing a loaded wheelbarrow.

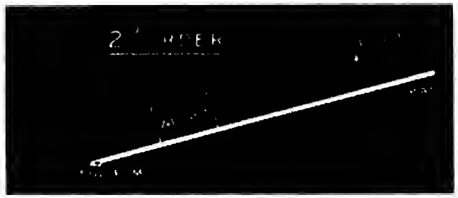

Fig. 75

Lever of the Third Order.—In this order the power is applied at some point situated between the fulcrum and the weight (fig. 76).

Example. — A pair of spring garden shears.

Before we can fully understand the effective use of such levers we have to consider the relative value of each arm of the lever.

You will understand this more readily by reference to the favourite see-saw. Here two boys arrange themselves at opposite ends of a plank which is supported on a fulcrum, and you know that they change their position until each balances the other. Should the two boys happen to be of exactly the same weight, then they will occupy positions equidistant from the centre. If, however, one boy is much heavier than the other, then the boy who is heavier must move nearer to the centre in order to maintain the "balance". It is possible to discover the exact position each boy must occupy if we know the weight of each. This is done by the principle of the "moments of force". The term "moments of force" is simply a "number" obtained by multiplying a known force by a known distance, and these numbers enable one to compare the effectiveness of such forces when acting at a distance from the fulcrum. Taking the case of the see-saw; suppose the boy at A (fig. 77)

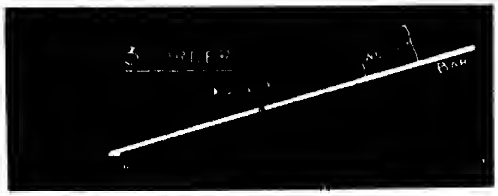

Fig. 76

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weighs 60 lb. and the boy at B weighs 70 lb., and A is 10 ft. from the fulcrum, where must B sit in order to balance A? By multiplying the weight of A by the distance from the fulcrum we have 60 lb. by 10 ft. = 600. The 600 represents neither pounds nor feet. It is merely a "number", which is called the "moment" of A, and represents its tendency to turn the plank about the fulcrum. What is the "moment" of B? This we do not know, because we have not yet discovered where he is to sit. This we do know: that if B is to balance A he must have a "moment" of 600, and, since we know B's weight, we have only to divide 600 by that weight, which will give B's distance from the fulcrum in feet:

Fig. 77

$$600 \div 70 \text{ lb.} = 8\tfrac{4}{7} \text{ ft.}$$

Hence it will be clearly seen that the greater the distance at which the force acts, the greater will be the tendency to turn; that is, the greater will be the "moment" of the force. Thus by the principle of moments we are enabled to compare and contrast the efficiency of levers.

Fig. 78

Having thus defined the lever and its various forms of application, together with the means of testing their efficiency, we are now in a position to examine various articles in the room which are used as levers.

A Door Handle.—The first example is found in the handle of the door, which is turned in order to lift the latch or bolt when entering a room. By means of the spherical knob one is able to exert a leverage on the bolt,

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thus lifting it with ease. A turning force is exerted on the rim of the knob (fig. 78). The moment of that force will be found by multiplying the radius of the knob by the force exerted.

AB × C = moment of force C.

In this case we cannot change the length of the lever, but the force can be increased by exerting more muscular effort, and thereby increasing the moment.

Fig. 79

A KEY.—The door key is another example (fig. 79).

Distance AB × force C = moment of C.

THE BRADAWL.—This has a pear-shaped handle (fig. 80). The shape and size of the handle enables us to grip the handle with ease; but its size does more than that: it enables us to exert a considerable turning moment on the handle.

Again, distance AB × force C = moment of C.

If either the distance A B or the force C be increased, the turning moment or effectiveness of the instrument will thereby be increased. You will readily understand that there must be a limit to the size of the handle. A very large handle would prove very uncomfortable had we to execute much work with it. Again, a large handle would be required only where a large force was necessary. That would only be in the case of large holes, and bradawls are not suitable for boring large holes, as they do not remove the wood. What happens, then, when we wish to bore large holes?

Fig. 80

THE GIMLET.—Notice the peculiar arrangement of the parts. It is like a letter T. Why is this? Examine the lower part, and at once you notice that it will bore a much larger hole than the bradawl we have just been discussing. Consequently greater force will be required for the purpose of turning it. This can be obtained in two ways:

(a) By increased muscular effort on the part of the user.
(b) By increased leverage.

On examining fig. 81, we see that the distance AB is

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much greater than it was in the bradawl. Hence the "moment" of C will be greater. Therefore, by exerting the same muscular force at C as was done in the case of the bradawl, we are enabled to overcome a much greater resistance or bore a larger hole. You will see that, had the handle been made the same shape as the bradawl's handle, how inconvenient it would have been to grasp such a large handle. Further, there is a tendency for the hand to slip round the smooth surface of the bradawl handle, whereas there is no such tendency in the case of the gimlet, the force in this case acting directly on the cross handle. Another advantage gained by having handles of this particular shape is that much deeper holes can be bored. We have an extension of the "gimlet principle" in the auger.

Fig 81

THE AUGER.—This is an enlarged form of gimlet used for boring large and deep holes (fig. 82). Extra force can be applied by the use of both hands. The force exerted by each hand produces its own moment. The sum of these moments gives the effective turning moment of the combined forces. Hence

$AB_1 \times C + AB_2 \times C_2 =$ moment of $C_1 + C_2$.

Fig. 82

Should the resistance be very great, the turning moment can be increased by passing a longer bar "lever" through the handle.

Note.—Augers are not used for manual-training purposes, but reference is made to them here for the purpose of explaining the principle.

THE BRACE.—Examine the brace. We find in it only another example of the application of the lever. The particular shape is known as the "crank". (Fig. 83.)

Again, the distance A B × force C = turning moment of C.

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The distance AB in this case is clearly much greater than it was in the bradawl and gimlet. Again, the peculiar structure enables us to exert a much greater muscular force. In the gimlet the force was exerted by the thumb and fingers only, whereas in this example we may grasp the handle at A firmly in the hand and exert force from the elbow and shoulder. This greater force is necessary by virtue of the downward force exerted at D. The distance AB cannot be indefinitely increased; otherwise, when in use, the brace could not be conveniently turned. The usual distance is 4 to 5 in., thus giving a "sweep" of 8 to 10 in.

Fig. 83

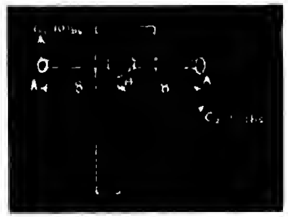

Fig. 84

Various devices are in use for increasing both power and speed, but these do not come within the range of manual training.

THE BENCH SCREW.—This is another example of double leverage (fig. 84). When we wish to tighten the vice and grip a piece of work we exert forces at C_1 and C_2; each force has its own moment, which will vary according to the position of the lever in the screw of the vice. The following will serve as examples:—

(*a*) *When the lever is centrally arranged.*

Let the lever be 16 in. long, and suppose a pulling force of 10 lb. be exerted at C_1 whilst a pushing force of 16 lb. is exerted at C_2, then—

$$A_1B \times C_1 + A_2B \times C_2 = \text{effective moment.}$$
$$8 \text{ in.} \times 10 \text{ lb.} + 8 \text{ in.} \times 10 \text{ lb.} = 160.$$

(*b*) *When the lever is not centrally arranged* (fig. 85).

Let the pulling and pushing force still be 10 lb. Then again we have—

$$A_1B \times C_1 + A_2B \times C_2 = \text{moment of } C_1 + C_2$$
$$4 \times 10 + 10 + 12 =$$
$$40 + 120 = 160.$$

Comparing this moment with the moment in the former example, we see that they are equal; hence the work done in each case is the same.

(c) *When the lever is at one side and the dual forces act at the free end* (fig. 86).

First, we must notice that a portion of the lever is lost in consequence of

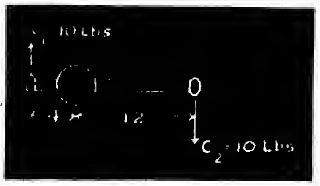

Fig. 85

Fig. 86

the diameter of the head of the screw. Assuming the diameter of the head to be 4 in., the free arm of the lever will be 14 in. long. Then—

$$AB \times C = \text{moment of } C.$$
$$14 \times 20 = 280.$$

Comparing this moment with the moments in the previous examples it is clear that a great mechanical advantage has been gained, though the force applied remained constant.

THE LEVER OF THE IRON VICE.—This affords another example. It will be seen that the lever is short compared with the lever in the "wooden screw" vice. The reason for this will be more readily seen when the action of the "wooden screw" and the "cam" of the iron vice is compared.

Fig. 87

THE GRINDSTONE. — When grinding a tool we know that the tool is pressed on the outer rim of the stone. This pressure is acting at a distance from the centre—i.e. axis of the stone—and varies as the diameter of the stone. The pressure on the tool multiplied by the radius of the stone will give a moment which acts against, or resists, any effort to turn the stone. How is this to be overcome? Clearly it cannot be overcome by exerting muscular effort *directly* on the axle which passes through the stone. Let us examine such a case.

Suppose the stone to be 24 in. diameter (fig. 87), and the axle at A 1 in.

diameter. The force C, due to pressure and friction on the tool, we will assume to be 20 lb. Neglecting all other considerations due to friction, &c., what muscular force would have to be exerted on the rim of the axle at A in order to turn the stone?

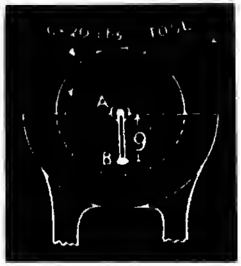

Fig. 88

Turning moment = moment of resistance.

Muscular force $\times \frac{1}{2}$ in. = 20×12

= 240.

Muscular force = 240×2

or 480 lb.

Clearly this cannot be done, nor is it advisable to try to do it when by means of the crank principle or lever we can reduce the expenditure of muscular effort. Let us therefore take the case of a crank arm and ascertain what turning force must be exerted (fig. 88).

Assuming the crank AB to be 9 in. long, we have—

Turning moment = resistance moment.

Muscular force $\times$ 9 in. = 20×12.

$$\text{Muscular force} = \frac{20 \times 12}{9}.$$

Muscular force = $26\frac{2}{3}$ lb.

Fig. 89

Therefore the person turning the stone must push with a force of approximately $26\frac{2}{3}$ lb.

This could be reduced by increasing the length of the crank arm, but increase in this direction makes it inconvenient for turning. Or the pressure on the tool may be reduced, thereby decreasing the resistance of C.

Grindstones Fitted with Treadle.—Here we have an application of a lever of the second order, in which the weight is between the fulcrum and the power. Let us investigate an example (fig. 89).

We will assume the following conditions:—Diameter of stone 24 in.; small crank AB 3 in.; resistance 20 lb.; foot lever 24 in. long, connecting rod attached at E 12 in. from D.

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Find the force which must be exerted by the foot at F.

Let us first ascertain the force that must be exerted at B in order to turn the stone, and from that calculate the force that must be exerted by the foot at F in order to produce the required result at R.

$$\text{Again, turning moment} = \text{moment of resistance.}$$
$$\text{Force at B} \times 3 = 20 \times 12$$
$$\text{Force at B} = \frac{20 \times 12}{3} = 80 \text{ lb.}$$

Therefore the force of 80 lb. at B is acting through the connecting rod BE and tending to prevent the lever DF being moved by the foot. The moment of resistance for the force will be found by multiplying the weight into the distance from the fulcrum at which such weight is acting.

Hence we have—

$$\text{Moment at F} = \text{moment at E.}$$
$$\text{Muscular force} \times 24 \text{ in.} = 80 \times 12.$$
$$\text{Force at F} = \frac{80 \times 12}{24} = 40 \text{ lb.}$$

THE BOW SAW.—In order to prevent the narrow blade from buckling when in use it is essential that it shall be in a state of tension, i.e. subjected to a pulling force. This is accomplished by means of the frame into which the saw is fixed (fig. 90). Each side piece of the frame is a lever of the first order, the ends of the middle beam acting as fulcrums. The beam is nearer to the string than the blade. Let us suppose that, in order to keep the blade tight, it is essential to have a tensile stress of 20 lb. acting along the blade. What force must be exerted at the top end of each lever in order to produce the required stress? The distance AC = 5 in. and AB = 4 in.

Fig. 90

$$\text{Moment at B} = \text{moment at C.}$$
$$\text{The force} \times 4 = 20 \times 5$$
$$\text{The force} = \frac{20 \times 5}{4} = 25 \text{ lb.}$$

THE MORTISE CHISEL.—The mortise chisel when in use not only severs

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Fig. 91

the fibres, but is also used as a lever for removing the waste—i.e. core of the mortise. Here again is an example of the lever of the first order.

The chisel is 10 in. long, and it has been driven 1½ in. into the wood (fig. 91). It is found that a force of 8 lb. must be exerted on the handle 2 in. from the top end in order to overcome the frictional resistance of the core. What is the lifting power at the cutting end of the chisel?

$$\begin{aligned} \text{Moment at C} &= \text{moment at A.} \\ \text{Lifting power C} \times \text{CB} &= \text{force at A} \times \text{AB.} \\ \text{Lifting power C} \times 1\tfrac{1}{2} &= 10 \times 6\tfrac{1}{2}. \\ \text{Lifting power} &= \frac{10 \times 6\frac{1}{2}}{1\frac{1}{2}} \\ &= \frac{10}{1} \times \frac{13}{\cancel{2}} \times \frac{\overset{1}{\cancel{2}}}{3} = \frac{130}{3} \\ &= 43\tfrac{1}{3}\ \text{lb.} \end{aligned}$$

This problem should enable scholars to understand why it is necessary to make mortise chisels so strong. Clearly a small force applied at the end of the handle is capable of exerting a fairly big moment, and, provided there is resistance at the other end of the lever, the moments of force and resistance are tending to break the chisel at the fulcrum B.

Fig. 92

THE PINCERS.—The pincers presents an example of a double lever of the first order (fig. 92), the rivet at the base of the jaws acting as a fulcrum. This rivet is situated much nearer to the "gripping end" than to the "power end". Comparing these distances we find they are in the ratio of approximately 6 to 1.

What will be the gripping force of the jaw assuming that the ends at A are drawn together with a force of 6 lb.?

$$\begin{aligned} \text{Moment at C} &= \text{moment at A.} \\ \text{Gripping force at C} \times \text{BC} &= \text{force at A} \times \text{AB.} \\ \text{Gripping force at C} \times 1 &= 6 \times 6. \\ \text{Gripping force C} &= 36\ \text{lb.} \end{aligned}$$

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THE PINCER WHEN IN USE.—We have an example in this case of the use of a bent lever. (Fig. 93 shows the pincers as they would appear in actual use, and fig. 94 shows the problem in diagrammatic form.)

In order to find the upright lifting force the length of the lifting arm must be measured perpendicular to the line of action of such force, as BC. The power arm is the distance AB. The distance BC is exceedingly small as compared with AB, but it will be seen that the ratio is constantly changing as the nail is extracted.

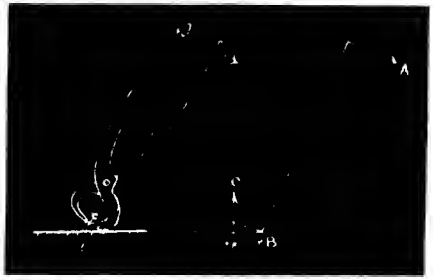

Fig 93 Fig 94

Assuming that the ratio between AB and BC is as 20 to 1, what force must be exerted at A in order to overcome a resistance of 200 lb.?

Again, by the principle of moments—

Moment of the force = moment of resistance.
The force × AB = 200 lb. × BC.
The force × 20 = 200 × 1.

$$\text{The force} = \frac{200}{20} = 10 \text{ lb.}$$

Hence by exerting a force of 10 lb. we are enabled to secure a lifting force of 200 lb. This 200 lb. resistance has to be supported by the material immediately under that part of the pincers which is acting as a fulcrum. Hence it is that we find a very light force exerted on the end of the arms of the pincers is sufficient to "bruise" the surface of the work.

Note.—Demonstrate this fact.

Many other examples of levers in connection with the tools used in the manual-training room will readily be found.

Inclined Plane and Screw. — THE INCLINED PLANE.—All wedges afford examples of the inclined plane, and the principle was lightly touched upon when dealing with the cutting action of the chisel. We shall, however, find many other examples.

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THE WEDGE OF A PLANE.—The wedge of the jack plane is formed by two surfaces which intersect at an angle of about 10°. We have already seen that—

(a) For all action there is a reaction.
(b) The reaction of a surface is at right angles to the surface.

Calculate the pressure of the wedge on the iron of the plane and on the wedge abutments, assuming that the blow delivered on the end of the wedge is equal to a force of 20 lb.

Fig 95

Let A B C (fig. 95) represent a section of the wedge, the angle at A being approximately 15°, or such that the ratio of A C to C B is as 4 to 1. The force of the blow as shown by the arrowhead acts parallel to A C, and the reaction of the surface A B (R_1) is at right angles to A B. Similarly the reaction of the surface A C (R_2) is at right angles to A C. Then by the triangle of forces we can determine the value of each.

From C draw C D perpendicular to A B, and from B draw B D perpendicular to B C.

Then the triangle B C D represents the magnitude and direction of each of the forces. That is, B D represents a force of 20 lb., but B C : B D as 4 : 1.

$\therefore$ B C $= 20 \times 4 = 80$ lb. and D C $= \sqrt{20^2 + 80^2} = 83$ lb. approx.

That is, R_1 = approximately 83 lb. and R_2 = 80 lb.

Note.—The wedge is retained in position due to the friction set up between the surfaces of the wedge and the surfaces upon which they rest. If the angle were large the effectiveness of these forces would be considerably reduced, and there would be a tendency for the wedge to slip back.

THE CHISEL USED FOR SPLITTING WOOD.—The chisel is often used for the purpose of splitting pieces of wood. By comparing the forces necessary to split pieces of wood differing in kind, but having the same dimensions, an approximate estimate of their relative toughness can be formed. The toughness is due to the interlacing of the fibres and cohesion of the particles.

A firmer chisel, having its face and sharpening bevel inclined at 35°, is used for splitting a piece of wood. It is found necessary to deliver a blow acting on the handle with a downward force of 30 lb. in order to split the wood (fig. 96).

(a) Find the resistance at the surfaces of the chisel.

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(*b*) Find the rectangular components of the force due to the reaction of the inclined face of the chisel.

Fig. 96

Applying the triangle of forces, and drawing our figure to scale as follows:—

Let A B (fig. 97) represent the force due to the blow in magnitude and direction.

From A draw A C at an angle of 55° to A B. This represents the direction of the force due to the action of the inclined surface.

From B draw B D at right angles to A B. Then B D represents in magnitude and direction the force due to the action of the face of the chisel.

Fig. 97

A D represents the magnitude of the force exerted by the inclined surface of the chisel.

If these angles be carefully plotted out it will be found that they are to one another approximately in the ratios 3 : 4 : 5.

A B = 3. B D = 4. A D = 5.

and since A D = a force of 30 lb.

B D = „ „ 40 lb.

and A D = „ „ 50 lb.

Having determined the value of each force we have now to consider the rectangular components of the force exerted by the inclined face of the chisel. Upon careful examination it will be found that the same triangle represents these forces, but the sense of the horizontal components must be reversed, i.e. reverse arrowheads. This being the case, the horizontal force due to the inclined face is equal to the force exerted by the perpendicular face of the chisel. That is, the blow delivered on the end of the chisel handle acts with outward horizontal forces of 40 lb.

The Screw.—The screw may be considered as a further illustration of the inclined plane, but instead of the inclined surface continuing in a direct straight line it is arranged, or wound, round a cylinder. This can readily

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be illustrated by winding a triangular piece of paper round a cylinder as shown in accompanying figure (fig. 98). Cut a long acute-angle triangle from a piece of paper and wind it round a cylindrical piece of wood as shown.

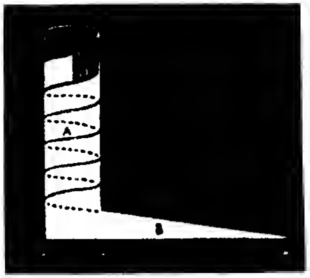

Fig. 98

The top part A shows the screw-like appearance, whilst at B is shown the free, unwound portion indicating the true shape of the plane.

The screw has the advantage that it institutes a very long inclined plane which can be continuously actuated by rotating instead of moving in a direct line through a great distance as in the case of an ordinary wedge.

THREAD AND PITCH.—The inclined edge which winds round the cylinder is known as the "thread", and its inclination for any given cylinder is determined by the distance from any point on the thread to a corresponding point after the thread has traversed once round the cylinder as shown at C D in fig. 98. The distance is known as the "pitch".

VALUE OF WORK DONE.—The amount of work done by the "turning force" exerted whilst turning the screw through one revolution equals the amount of work done by the pushing or pulling force of the screw acting through a distance equal to the pitch. That is—

F = turning force exerted in pounds (lb.).
C = circumference traversed in inches.
P = the pull or push of the screw.
p = pitch of the screw in inches.

Then $F \times C = P \times p$.


Fig. 99

This calculation makes no allowance for "friction" between the parts, which will vary according to the material of which the screw is composed and the condition of the surfaces of contact. It will be well to estimate this at 70 per cent for iron screws and 80 per cent for wooden screws.

THE BENCH SCREW.—*Problem.*—What force

can be exerted by a wooden bench screw under the following conditions (fig. 99)?

Turning force 20 lb.

Diameter of screw $2\frac{1}{2}$ in. (circumference = $2\frac{1}{2}$ in. × $3\frac{1}{7}$ in. = $7\frac{6}{7}$ in., approx. 8 in.).

Pitch of screw $\frac{3}{4}$ in.

Friction 80 per cent.

Then $F \times C = P \times p.$

$$20 \times 7\tfrac{6}{7} = P \times \tfrac{3}{4}$$

$$P = \frac{20 \times 55 \times 4}{7 \times 3} = \frac{4400}{21} \text{ lb.}$$

But only 20 per cent or $\frac{1}{5}$ is effective.

$$\therefore \text{ net value of } P = \frac{4400}{21 \times 5} = \frac{880}{21} = 41\tfrac{19}{21} \text{ lb.}$$

Other examples will be found in—

(*a*) The screw of the cramp.
(*b*) The bench holdfast.
(*c*) The marking gauge.
(*d*) The mortise gauge.
(*e*) The G. cramp.

Note.—It must be clearly borne in mind that many conditions enter into the calculations of such a problem which it is not within the province of manual training to touch upon. All that can be done here is to acquaint the scholars with the principles underlying such problems.

Centrifugal Force.—A thorough investigation of problems relating to centrifugal forces would carry us beyond the range of manual training, yet the subject should not pass unnoticed.

Centrifugal force is that force by which all bodies moving round another body in a curve tend to fly off at any point of their motion in the direction of a tangent to the curve.

Sufficient evidence of this tendency will be found in the familiar example of boys throwing pug from the end of a stick, or in the case of the sling, by means of which stones can be propelled to an enormous distance. Boys are familiar with the fact that the distance to which the stone can be propelled depends upon three conditions:

(*a*) The weight of the stone.
(*b*) The length of the string.
(*c*) The rapidity with which the string is turned, i.e. velocity.

For a portion of the journey the object (pug or stone) was compelled to move in a circular path, but when released from the stick or string it endeavoured to travel in a straight line; but the pull of the earth (gravity) caused it gradually to approach the earth and finally brought it to a state of rest. It is evident that for the missile to have continued travelling on its circular path for a given period some force must have been exerted, and that it was only when this force was overcome or ceased to act that the body flew off in the straight line, i.e. tangential to the path of rotation. The force acting was that known as centrifugal force, and it can be accurately measured.

Example.—Take a stiff piece of elastic or rubber, such as a boy would use in making a catapult. Attach a weight to one end. Now whirl the body round in a circle, and it will readily be seen that the faster the body is whirled the more is the elastic stretched. Determine the amount by which the elastic is stretched for any given number of revolutions per second. Having determined the amount of elongation, now attach the piece of elastic to the end of a spring balance, and pull on it until the elastic is again stretched to a distance equal to the amount of stretch due to rotation. The reading on the balance will give approximately the value of the centrifugal force.

Should several experiments be tried, varying the conditions (*a*), (*b*), (*c*) formerly stated, their influence will be determined.

Suppose a body to be revolving with a velocity of 10 ft. per second, and the radius of the circle to be 2 ft. Divide the square of the velocity by 2 ($10^2 \div 2 = 50$), and the pressure is such that, were it to take the place of gravity, the weight being allowed to fall would at the end of 1 sec. have acquired a velocity of 50 ft. per second, which approximately is the case with bodies allowed to fall freely to earth.

Now, the centrifugal force exerted by any given weight moving under these conditions will be such a proportion of the weight as 50 is to 32. Suppose a weight of 5 lb. is moving under the above conditions, what will be the amount of the centrifugal force? Then—

$$\frac{50}{32} \times \frac{5}{1} = \frac{250}{32} = 7\tfrac{13}{16} \text{ lb.}$$

We have examples of the application of these principles in the use of the hammer and the mallet.

NOTES

INERTIA, MOMENTUM, FRICTION, TENSION, COMPRESSION, STRESS, STRAIN, IMPACT

These are terms in frequent use in the classroom, but space will only permit of these being mentioned in a general way.

Inertia is that property which all matter possesses, and which causes it to remain at rest when in a state of rest, or to remain in motion once in a state of motion. Examples will be found in all tools which, under ordinary conditions, remain in a state of rest. Force must be exerted in order to overcome the inertia of the tool. The force used in the manual-training classroom takes the form of muscular effort, the effectiveness of such force being increased by judicious use of the various mechanical principles already considered.

One familiar example of the property of inertia will be found in the various planes used. When we desire to loosen the wedge we do not apply our force *direct* to the wedge, but strike the body (*stock*) of the plane. Why is this? The reason is that both stock and wedge are in a state of rest, and will remain so until some force is brought to bear upon them. The blow delivered on the stock overcomes its inertia and sets up motion, but the blow did not act directly on the wedge, therefore its inertia tended to keep it in a state of rest. We have, then, the wedge remaining at rest whilst the stock is in motion, and consequently the wedge is released from the stock.

Other examples occur in the driving of nails, turning of screws, &c.

Momentum.—When we consider masses in motion we can readily perceive that, given that a body of known mass moves with a certain velocity, it will be capable of exerting a certain force; and, further, should either the mass or the velocity, or both mass and velocity, be increased, then the force exerted by such moving mass will be increased. Similarly, if either mass or velocity be decreased, then the resultant force is decreased. The measure of the force which mass in motion is capable of exerting is called the "momentum of the mass". It is found by multiplying the number of units of mass by the number of units of velocity.

This much of the work performed by the various tools is due to the effect of momentum in overcoming the resistances against which such tools operate.

The Jack Plane.—Let us suppose the case of a jack plane having no weight (mass); under these conditions, all the work done would be the result

of direct muscular effort in causing the cutter to move forward against the resistance of the wood. But the stock of the plane has weight (mass), and when we impart a velocity to this mass the force exerted by the product of mass and velocity is capable of overcoming a much greater resistance, thus relieving us of the necessity for exerting so much muscular effort (force).

The truth of this statement can be tested by making a comparison between the amount of effort required to push forward—

(*a*) A smoothing plane,
(*b*) A jack plane,
(*c*) A trying plane,
(*d*) A jointing plane

The conditions under which such a test must be carried out are as follows:—

(*a*) Planes equally sharp.
(*b*) Equal amount of cutting iron in action.
(*c*) Set to the same degree.
(*d*) Applied to the same piece of wood.
(*e*) Moved with the same velocity.

THE HAMMER.—The effectiveness of the blow from a hammer depends upon its momentum. For any given hammer the mass remains constant, but it is evident that the velocity can be varied, and therefore its momentum can be varied. When we wish to deliver a light blow with the hammer we do so by actuating the hammer from the wrist, thereby reducing the length of the arc through which the head moves in a given time, thus reducing its velocity. Should a heavier blow be required, the hammer is then actuated from the elbow, thereby increasing the length of arc through which the head travels, thus increasing the velocity, provided the hand moves with the same velocity as in the previous example. Again, the velocity can be increased by actuating the hammer from the shoulder, and thereby increasing its momentum. If necessary to exert a greater force, then the momentum must be increased by taking a hammer having a longer handle, or a heavier head, or by combining both.

Compare the momentum of light and heavy hammers, short- and long-handled hammers.

Experiment.—Take a piece of pine or poplar and deliver blows upon the surface, striking from—

(*a*) The wrist; (*b*) the elbow; (*c*) the shoulder,

the rate of revolution to be the same in each case. Compare the effects of the blows. Repeat the experiment, using a heavier hammer. Repeat the experiment, using a heavier hammer, with longer handle.

Having enquired into the effect of masses moving with varying velocities, and ascertained that, by increasing either the mass or velocity such a body is capable of imparting greater force or executing a greater amount of work, we are in a position to understand the value of the heavy "mass" possessed by the grindstone. This mass, revolving at a fairly high rate of speed, i.e. rim velocity about 800 ft. per minute, acquires an enormous momentum, and thereby is assisted in overcoming the resistance set up by the pressure on the tool being ground and reducing the amount of muscular effort to be exerted. This reduction cannot take place until the "inertia" of the stone has been overcome and "momentum" acquired. Thus, theoretically, the tool should not be applied to the stone until the stone is running with the maximum velocity and momentum; in practice the tool is adjusted on the stone, but the full amount of pressure is not exerted until the maximum velocity has been attained.

Reference can be made to the flywheel on an engine, which, by virtue of its momentum, regulates and causes uniform motion in the working parts of the engine.

Friction.—When two bodies are in contact there is a tendency in such bodies to resist sliding motion. This resistance is known as "friction". The amount of friction varies according to the nature of the surfaces in contact, and increases in proportion to the increase of mass in the sliding body.

The velocity of moving bodies does not affect the "amount" of friction, but it does influence the effect of friction, as will be seen hereafter.

Friction acts as a mechanical agent in delaying the action of a force, but cannot of itself generate force. One of the greatest difficulties which the engineer has to face in the case of machines is how to overcome the resistance to sliding.

We shall find that friction plays a very important part in our manual-training lessons.

Experiment.—Compare the frictional resistance of various kinds of woods used in the manual-training lessons. This can be accomplished in the following manner: Prepare pieces of wood, of various kinds, about 24 in. by 3 in. by ½ in., having one surface planed smooth and true, the other surface being allowed to remain rough. Next prepare blocks of wood about 3 in. by 2 in. by 1 in., having one surface smooth and the other rough. The

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large pieces will serve as inclined planes over which the smaller pieces can slide.

Rest the plane in a horizontal position, having its smooth surface uppermost, and on it place one of the small blocks having a smooth surface in contact with the plane. Now gradually raise one end of the plane until the block C commences to slide down the plane; then measure the angle D by means of a protractor (fig. 100).

What caused the block to remain at rest whilst the plane was moving through varying angles until it arrived at D? What caused it to slide down the plane when the angle D was reached?

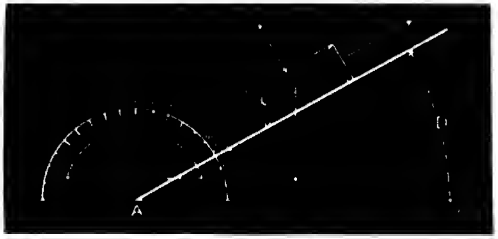

Fig. 100

In the first case we have seen that gravity is acting on the mass and tending to pull it towards the earth. This pull is measured in terms of "the weight of the mass", and, whatever be the inclination of the plane, this force continues to act vertically downwards from the centre of gravity of the mass; but having moved the plane through a small angle, it is found that the block continues in a state of rest, due to the resistance to sliding of the surface. When the plane was in a horizontal position the forces acting—i.e. the weight of the mass and its reaction—were mutually perpendicular to the plane; but immediately the plane is inclined, then these forces are not acting in the same straight line, for, whilst the weight of the block is acting vertically downward, the reaction of the inclined plane is at right angles to its surface, as in fig. 100; but two forces can produce equilibrium only when they act in the same straight line and are equal and opposite. Clearly, then, if the block remains at rest, some other force is acting on the block, and in this case the force is due to friction. This retarding force must act in a line parallel to the surface of the plane and up the plane. When the plane has been sufficiently inclined to ensure that the action of the two forces—i.e. pull of gravity (weight) and the reaction of the plane—is sufficient to move the block from a state of rest, then it is that the two forces are just slightly in excess of the third force, which we have seen is due to friction. By applying the principle

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of the triangle of forces, each force acting can be definitely measured. Fig. 101 shows in a diagrammatic form the ratio of these forces.

The experiment should make quite clear the fact that this triangle is true only in the case where the body commences to move. It is clear that as the plane is raised the sides of the triangle forming the right angle vary, whilst the hypotenuse—representing the weight of the mass—remains constant. Therefore the correct angles for the triangle of forces will be determined when the plane has been lifted through an angle sufficiently to cause the body to slide down the plane.

Fig. 101

Having performed the above experiments, and compared the frictional resistance offered by various materials under varying conditions, we are now in a position to investigate a few of the problems of the manual-training room.

THE BENCH SCREW.—This, being made of wood, offers considerable resistance to motion, due to the friction between the sliding surfaces, and we have seen the amount of friction is in proportion to the mass (or pressure on the surfaces in contact).

It will readily be understood that when an object is being gripped in the vice the force of this grip is transmitted to the surfaces of the screw in contact, thereby setting up an enormous amount of friction, and until the resistance due to friction is overcome there can be no motion; hence much of the force exerted on the end of the turning lever is exerted in overcoming this resistance. We have further noticed in our experiments that the harder and smoother the surfaces in contact the smaller is the amount of friction. The bench screws are made of beech, which is by no means one of the hardest of woods; but it has many other advantages fitting it for such a use. There is then a considerable amount of friction between two surfaces of beech. In order to reduce this friction the screw is coated with black lead (plumbago), which fills the pores of the wood and presents smooth working surfaces. Black lead has the disadvantage that it can be used obviously only on surfaces which have not to be handled.

THE SCREW OF THE MARKING GAUGE.—We have seen that these screws are made of boxwood, which is an extremely hard wood, and which can be brought to an exceedingly smooth surface, thus reducing the amount of

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Brass is by no means the strongest and best material for withstanding tensile forces; yet seeing that its ultimate tensile strength is approximately 28,000 lb. per square inch, it will readily be seen that a thin band of brass will answer all requirements of the chisel.

NAILS VERSUS SCREWS.—Reference should be made to the advantage of using screws as compared with nails for fixing the parts of a structure together which are likely to be subjected to tensile stresses.

Nails having a continuous unbroken surface can grip the wood with a resistance only equal to the amount of friction and compression set up, and due to the displacement of the fibres of the wood whilst the nails are being driven in; whereas with screws the flange—thread—cuts into the wood and offers a direct resistance to tensile stresses apart from compression and friction.

Refer to other examples in the room of bodies in tension.

Compression.—When we so press on a body that we make it occupy a smaller space we are said to "compress" the body. That is, a given quantity of matter is made to occupy a smaller volume; hence it becomes denser. Forces which tend to compress bodies are known as compressive forces, and the body so compressed is in a state of compression.

Experiments.—(*a*) Take a piece of soft wood, and, having carefully measured its thickness, fix it in the vice and screw it very tightly. Undo the screw and measure the thickness again. What do you notice? Why?

(*b*) Deliver a few heavy blows with a hammer on the surface of a piece of soft wood. Where is the material that originally filled the hollows made by the hammer? What has been done to fibres of the wood struck by the hammer?

(*c*) Take the point of the hammer, and, rubbing in the direction of the fibres of the wood, so form a groove. What has been done to the wood where the groove is so formed?

(*d*) Take a piece of wood about 6 in. by ½ in. by ½ in. and fix it in the cramp with its ends against the jaws, and tighten the screw. What causes the piece of wood to bend?

(*e*) Deliver a heavy blow with the mallet on the handle of a chisel. What happens to the fibres of the chisel handle? What happens to the fibres of the mallet head?

Explain why it is that mallet heads often split after being much used.

(*f*) Drive a large nail into a piece of wood and then split the piece of wood so as to show the effect of the nail on the fibres of the wood. What effect has the nail on the fibres of the wood?

Refer to examples in room of bodies in a state of compression.

CHAPTER XII

Geography of Manual Training

General.—Trees, like animals, are found growing in nearly all parts of the world, and just as we find characteristic animals so do we find characteristic trees in the various parts. From the northern snowline to the southern snowline vegetation of some kind exists, and from sea level to the snowline of the various mountains of each and every country there is vegetation.

The very existence of man depends upon the existence of such vegetation, and the comfort of his dwelling is dependent upon the trees found, for in every part of the world where man exists we find him adapting timber to his needs in framing his houses, and in providing furniture and utensils for use in the home. Even to-day, when we live in what might be termed the "Iron Age", we cannot do without timber. The natives of the tropics, whose habits and customs are of the rudest, and who provide themselves with little or no clothing, yet find it necessary to provide themselves with shelters for protection at night. These have a rough framing of wood and a covering of mud, grass, or leaves of some kind.

Consider, too, the question of fires, and think of the enormous quantities of wood consumed for the purpose of providing warmth and for cooking food.

In many countries nothing but wood is used in the construction of houses, and wood forms the chief kind of fuel.

We are so familiar with its use, and consider ourselves so well supplied, that we take little heed of the sources of supply, and think but little of the provision for the future. This is an error for which future generations will some day suffer. It is essential that the question of forestry receive more attention than at present. It is in the manual-training lesson that much can be done to encourage an interest in this question, and the scholars led to take up the planting of trees.

Migration of Trees.—Trees, unlike animals, have not the power to move about in search of food, or to change their habitat if the prevailing conditions are unsuited to growth. Where they are born there they live and die, entirely at the mercy of circumstances. Should the soil contain

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the necessary food elements, should the climatic condition prove suitable, they may thrive; if these fail, death may take place.

Whilst the trees themselves have no power to migrate, Nature has made wonderful provision for the distribution of trees to all parts of the world. Examine the seeds of different trees. Is it not the case that many are provided with a wing-like or downy apparatus which enables them to float in air and thus be carried from place to place by the agency of the wind? Do we not find that seeds form the staple food of most birds, who carry them many miles to their nests, dropping many or even passing many through their system in an undigested form? Is not this a favourable means of transferring seeds from the fertile lowlands of a country to the upper and more mountainous regions? Again, do we not find that many seeds float in water, and hence are carried along by any tiny little stream as well as by the mighty streams and vast oceans? Seeds thus transferred are at the mercy of the elements, and, for the few that fall on suitable soil and survive, many millions perish.

Man has now become the great distributing agent. We find him rearing young plants in protected situations, and later transferring them to the less-protected open spaces he wishes to cultivate. We find him taking trees from one part of the globe and transplanting them in another part, watching and tending them, and doing all within his power to enable such transplanted trees to adapt themselves to the changed environments.

Indigenous and Exotic.—It has been stated that trees, like animals, are characteristic of certain localities. Where trees are found growing naturally or forming part of the original flora of a country they are said to be *indigenous* (indigenous = originating or produced naturally in a country or climate), but in cases where they exist, but it is known that they have been transferred by man to such countries, they are said to be *exotic* (exotic = introduced from a foreign country). If we are to take an intelligent interest in the question of timber production, sources of supply, and commercial value we shall at once be led into a study of the geography of the world. We must pass in review each country, studying carefully its climate, soil, rainfall, rivers (whether such rivers are navigable or otherwise), coast line, people, animals, and even its railway systems. This in itself would form a complete study, yet somehow time must be found in our manual-training lessons to "point the way" to such an interesting study. Only the fringe can be touched in this work.

EUROPE

Europe is one of the five continents into which the land of the globe is divided. It has an area of about 3,700,000 sq. mi. It is divided into many countries and is inhabited by various races of people, with different habits, customs, and language. The population is estimated roughly at 400,000,000.

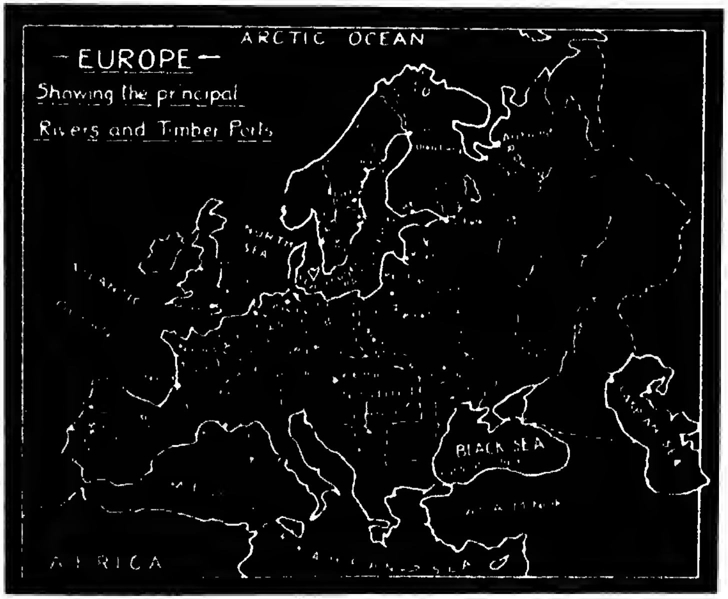

Fig 103

CLIMATE.—The climate of Europe is very variable. The variability is largely due to its position relative to the various seas which surround it, the peculiar arrangement of the mountain chains, which, running east and west, do not offer any impediment to the winds and currents borne in from the Atlantic and the large inland seas.

In the northern area the winter is extremely cold, lasting for about nine months, during which time the rivers and seas are frozen over and vegetation is at a standstill. The summer, which is short, is, however, comparatively hot, and vegetation progresses rapidly.

The southern area enjoys an exceedingly fine climate, snow and frost are seldom, if ever, seen, and vegetation flourishes uninterruptedly.

In the central area the four seasons are more nearly uniform in duration. The winters are cold, but not so excessive as in the northern regions, whilst the summers are warm, and vegetation conforms to these seasonal changes.

SOIL.—The soil throughout Europe generally is very fertile, and trees are found growing in practically all parts except the Steppes, which consist of low, treeless plains.

RAINFALL.—By virtue of its surroundings and the arrangements of its mountain ranges, Europe is abundantly supplied with rain, which is, to a great extent, uniformly distributed throughout the various seasons. In the southern area, however, whilst the rain is abundant during the three winter months of the year, there are often long droughts during the summer.

RIVERS.—Europe is abundantly supplied with rivers, and these play an important part in serving as waterways for the transport of her commerce, of which the supply of timber forms an important part.

The chief rivers are shown on the accompanying map. They are:—

Volga and *Ural*, which flow into the Caspian Sea and drain an area of 850,000 sq. ml. *Danube*, *Dniester*, *Dnieper*, *Don*, which flow into the Black Sea and drain an area of 900,000 sq. ml. *Oder*, *Vistula*, *Niemen*, *Dwina*, which flow into the Baltic Sea and drain an area of 900,000 sq. ml. *Rhone*, *Ebro*, *Po*, *Tiber*, which flow into the Mediterranean and drain an area of 250,000 sq. ml.

There are, of course, many smaller rivers, and though some are only a few hundred miles in length, yet they too serve as waterways, enabling timber to be brought from the interior.

THE COAST LINE.—Europe possesses a greater extent of coast line, in proportion to its area, than any other continent. There is approximately 1 ml. of coast line to every 190 ml. of area. This fact, coupled with the many navigable rivers, has largely contributed to her commercial supremacy. With few exceptions the countries of Europe have important towns on the coast which command the export and import trade. It is not difficult to understand that such towns are necessarily at the mouths of the various rivers.

PRINCIPAL TREES.—In the southern region the vegetation is more tropical in character, but even this region produces such trees as the oak, walnut, box, and mulberry. The central region produces the ash, alder, beech, birch, chestnut, elm, hornbeam, holly, larch, lime, poplar, pear, willow, pine, fir, and many others of a less important character.

PRINCIPAL TOWNS ENGAGED IN THE TIMBER TRADE.—Reference to the map will show at a glance the general outline of the country, with its rivers and towns engaged in the export of timber. The details can be amplified by reference to the large wall maps. A map of the world is essential for every manual-training classroom, and should be freely used during the lessons on timber.

FOREST AREAS.—THE BRITISH ISLES at one time contained vast forest areas, but owing to rapid increase in the population these quickly disappeared; one of the finest now remaining is the New Forest. In Scotland there are extensive forests, especially in Aberdeenshire and Inverness-shire.

NORWAY AND SWEDEN.—These countries are well wooded and produce principally pine, fir, birch, maple, and some oak.

RUSSIA AND POLAND.—These countries produce enormous quantities of timber. It is estimated that there are 200,000,000 ac. of cone-bearing trees, as pines, firs, &c., in addition to which large quantities of oak, beech, birch, maple, poplar, and hornbeam are yielded.

The principal forests are in the north, above latitude 65°.

Practically three-fourths of this vast area is covered with forests, the produce of which forms one of the main sources of revenue to the country. The Government supervise the forest areas in order to prevent waste, and the arrangements are such that certain areas are exploited annually and fresh trees planted, so that when the cycle has been completed the first area is again ready for cutting.

Many of the roads in Russia consist of tree trunks stretching across the road and laid side by side for many miles (corduroy roads).

Few ash trees are found in this region.

Pitch, turpentine, and tar are largely exported from Russian ports.

GERMANY.—It is estimated that about one-third the entire area of this country is covered with forests yielding pines, firs, oak, ash, chestnut, hornbeam, poplar, elm, maple, beech, birch, lime, and walnut.

AUSTRIA-HUNGARY.—Area about 264,000 sq. ml., of which about 88,000 sq. ml. are covered with forests, the character of the trees being similar to those mentioned for Europe generally.

Denmark has but few forests, and an effort is being made to extend these.

Holland is fairly well wooded and supplies the usual varieties of European woods.

France, whilst possessing numerous forests, has many demands upon its supplies, and therefore exports but little.

Spain and Portugal have but few forests; they are, however, the chief countries whence are drawn the supplies of cork, obtained from the cork oak (*Quercus Suber*).

Italy, whilst not possessing many forests, is noted for its walnut.

Turkey.—In this country are found extensive forests of oak, walnut, sycamore, beech, chestnut, maple, box, and many fruit trees.

Switzerland abounds with forest trees, the principal being pine, fir, oak, and beech.

AMERICA

America consists of two great continents stretching from the Arctic region in the north to the Antarctic region in the south. The total area of these vast continents is about 15,000,000 sq. ml.. with a population of over 80,000,000. These continents are subdivided into many countries. For the purpose of this work these divisions will be treated as follows: Canada, United States, Central America, South America.

Canada.—Canada has an area of 3,654,000 sq. ml. and a population of approximately 5½ million, giving an average of about two persons per square mile. About one-tenth of this area, chiefly that portion lying to the east, between the coast and the Great Lakes, is inhabited.

Climate.—The climate is exceedingly healthy. Though extremely cold in winter the stillness of the air prevents undue inconvenience. Towards the coast the atmosphere becomes much more humid and the temperature more uniform.

Soil.—This for the most part is extremely fertile, and trees are found growing in all parts except the central plain.

Rainfall.—There is an abundant rainfall, but this is very uniformly distributed throughout the year. Much snow falls throughout the winter months, but this only serves to improve the condition of the land and the quality of the timber produced.

Rivers.—Whilst this country possesses many fine rivers, the chief waterway serving for the transport of timber is the *St. Lawrence*, including the Great Lakes, flowing into the Atlantic Ocean.

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The importance of this waterway through the southern area of Canada cannot be overestimated. The river, rising as it does in Lake Superior, passes in an unbroken line to the coast, — a distance of over 1800 mi. There are many rapids in its course, but these have been overcome by the formation of canals. The many lakes through which the river passes are

Fig. 104

fed by numerous smaller rivers, which, though not navigable for any great distance, yet serve for the transport of timber from the more remote parts to this great commercial highway. The area thus drained is 330,000 sq. mi. The western coast line is very broken. The chief port lies to the south, at the mouth of the Fraser River, i.e. Vancouver. The Fraser River flows into the Pacific Ocean.

Coast Line.—While possessing a great length of coast line, the greater

portion lies to the north, and is frozen for the greater part of the year. The eastern coast, south of parallel 50°, possesses the important ports of St. John and Halifax. The great commercial centres are situated on the St. Lawrence, hundreds of miles from the coast, i.e. Quebec, Montreal, Toronto.

Principal Trees and Forest Areas.—The vast forests in this area are probably the most important and extensive in the world. More than one-half the total area is covered with these forests, i.e. approximately 2,000,000 sq. ml. Canada annually exports timber to the value of nearly £6,000,000 sterling.

Trees.—This fertile region produces about sixty different kinds of trees, the timber of which has distinct commercial uses. The most important are: Pines, fir, cedar, birch, maple, oak, beech, ash, elm, poplar, hickory, butternut, black walnut, and many fruit trees.

Lumbering.—This term is applied in a general way to the timber industry. Men engaged in this work are known as "lumbermen". During the autumn months lumber parties are formed. They make their way up the various rivers, and select suitable places for pitching their camps. The work of felling proceeds during the winter months, whilst the streams are frozen. When the snow and ice begin to melt, the streams are swollen and carry down the timber to the main streams, where the logs are formed into rafts which float down the St. Lawrence to the various sawmills. They are then cut into squared logs ready for export.

United States.—The United States occupies the central region of North America, extending from parallel 49° in the north to parallel 25° north. The area is about 3¼ million square miles, and the population over 76,000,000, roughly about 26 to the square mile.

Climate.—In a region so vast almost every conceivable climate is experienced. The northern area is extremely cold in winter, enjoying a climate much the same as Canada, whilst, in the southern area the climate is all but tropical in character; here, too, the seasons are characterized by their two periods, i.e. the "wet" season and the "dry" season. The climate in the eastern countries and round the Gulf of Mexico is very humid.

Soil.—The soil varies in a great degree, but in the main is extremely fertile, and produces trees in great abundance.

Rainfall.—In the great central region around the Mississippi valley the rainfall is evenly distributed throughout the year, and a great quantity falls. The highlands of the Pacific coast receive but scanty supplies. Whilst in the

Eastern and Gulf States there is an abundant supply, in a few of the Western States there is practically no rainfall whatever.

RIVERS.—This vast area is extremely well supplied with water highways, the chief of which are the *Mississippi* (Great-water) and *Missouri* (Mud-water), with their many tributaries, flowing into the Gulf of Mexico. The total length of these rivers together is over 4000 ml. They drain an area of 1¼ million square miles, or approximately one-seventh of the whole of North America, and they provide a waterway for steam navigation of over 30,000 ml. The Missouri, which is an affluent of the Mississippi, has a length of 2900 ml. before it enters the Mississippi.

Other rivers flowing into the Gulf of Mexico are the *Rio Grande, Colorado*, and *Alabama*.

Many smaller rivers drain the eastern slopes and flow into the Atlantic, the most important being the *Connecticut, Hudson, Susquehanna, Potomac, Roanoke, Santee, Savannah.*

Draining the western or Pacific slope, and flowing into the Pacific Ocean, are the *Columbia, Sacramento, San Joaquin, Colorado.*

COAST LINE.—The eastern and southern coasts are very extensive, and it is here that the chief ports are situated. They are: New York, Boston, Philadelphia, Baltimore, Charleston, New Orleans, Mobile, Savannah. The principal port on the west coast is San Francisco.

Note.—It must be remembered that whilst these constitute the chief ports, many smaller towns, situated at the mouths of the smaller rivers, are engaged in the timber and other industries. The exports are usually shipped to the larger commercial centres for distribution.

FOREST AREAS AND TREES.—The whole of North America is divided into several botanical regions, each producing its own species of trees, which are in many ways distinctive in character.

1. *Lacustrine Region.*—This region comprises the basin of the St. Lawrence, extending to the northern limit of forest, comprising the eastern coast to parallel 43° north, from whence it curves in a south-westerly direction to the Alleghanies, again rising in a north-westerly direction to parallel 60° north in the Rocky Mountains.

The characteristic trees of this region are: Birch (five varieties), alder (two varieties), poplar (four varieties), fir (four varieties), pines (three varieties, including red and white pine), juniper (two varieties—junipers and red cedar), arbor vitæ, yew, larch, maple (three varieties), ash (three varieties), elm (two varieties), oak (four varieties), lime (basswood), and red beech. The

lime and birch are very abundant, in some places composing entire forests. Hornbeam and ironwood, together with other trees, are less abundant, but are also found.

2. *Appalachian Region.*—This region extends south below parallel 43° north, and contains all the eastern States as far west as the Mississippi and Ohio Rivers. It is extremely fertile in trees, yielding as it does the following:—

Pine (four varieties, including pitch pine), oak, chestnut, walnut, ash, hickory, willow, maple, logwood, buttonwood, apple, locust, tulip tree (*Liriodendron tulipifera*), live oak.

The forest regions in the Mississippi area yield large supplies of cottonwood, swamp oak, cypress, hickory, ash, plane. Juniper (pencil cedar or red cedar) is obtained from this eastern region.

3. *Campestrian Region.*—This region comprises the vast central prairies extending from Texas in the south to the Saskatchewan River (Swift-current) in the north (Canada). Trees are not plentiful in this region, a few being found in the vicinity of the rivers, and for the most part similar to those mentioned as characterizing the Mississippi portion of the Appalachian region.

4. *Rocky Mountain Region.*—This region comprises the tablelands extending eastwards to the great prairies from the mountains. It is very barren, except for a few trees found on the banks of streams. These are chiefly cottonwood, and trees of quick growth and spongy fibre.

5. *North-western Region.*—This region contains only the Oregon and Washington territories. This area produces trees of enormous size, owing largely to the abundant supplies of moisture and suitability of the soil. Amongst the trees produced in this district are the famous Oregon pines, often attaining a height of 300 ft. and a diameter of from 10 to 12 ft. Oak, ash, spruce, hemlock, alder, maple, yellow fir, and cedar are also found.

6. *Nevadian Region.*—In the provinces of Nevada and California are found the giant redwood tree Sequoia (*Wellingtonia gigantea*), also pines and cedars of enormous proportions.

7. *The Mexican Region.*—This region includes the three southern States of Arizona, New Mexico, and part of Texas. The trees produced in this region are not particularly numerous. They are semi-tropical in character.

From a survey of the above classification it will be seen that the forest areas form extensive belts along the entire eastern and western shores.

Alaska.—The southern portion of this province contains vast forests, yielding spruce, fir, hemlock, cypress, cedar.

Columbia.—The forests are very extensive, and yield mahogany, cedar, and various dyewoods.

England annually imports timber from the States to the value of about 2¼ million pounds sterling.

Mexico, Central America, Cuba, West Indies.—This region, consisting of a portion of the mainland and the various islands in the Caribbean Sea, falls mainly within the tropics. The country is mountainous, and there are few large rivers, though there are numerous small rivers which communicate with the interior. The climate in these regions is extremely moist and hot. The soil is very fertile.

The principal timber trees are mahogany, logwood, lignum vitæ (Jamaica and Bahama Isles), cedar (*Cedrela odorata*), Havana cedar.

Mahogany is divided into two classes. That coming from the islands (Spanish Mahogany) is close-grained and hard, and contains a chalky substance in the pores, owing to the fact that it grows in districts abounding in limestone. Mahogany from the mainland, known chiefly as Honduras mahogany, though straight-grained and fairly strong, is much softer and less durable in character, owing chiefly to the fact that it grows in swampy districts.

The chief exports are:—

(*a*) Spanish mahogany, from Cuba, Jamaica, Hayti.
(*b*) Honduras mahogany, from Mexico, Guatemala, Honduras (British), Nicaragua, Costa Rica.

The introduction of this wood into the market is quite interesting. The captain of a vessel who was in the habit of visiting this region carried some to England on his ship. This was handed on to a cabinetmaker for the purpose of making a bureau. The effect was so pleasing that the Duchess of Buckingham had some furniture made of the same kind of wood. Thenceforth it became a general favourite for furnituremaking.

METHOD OF OBTAINING HONDURAS MAHOGANY.—About the month of August parties of men, usually about fifty in number, under the charge of a captain, and accompanied by a "huntsman", proceed to the forest. Having pitched their camp in a suitable locality, the "huntsman" climbs one of the highest trees and locates the larger specimens. The work of locating the trees and directing the party to such requires considerable skill, which the "huntsmen" possess in a high degree. The best trees are sought out and cut down, then roughly squared and cut into suitable lengths for transport through the forests. The men themselves drag the logs—which are supported

on rude trolleys—to the river bank or swampy ground. The logs are marked with the owner's mark. This occupies the period during the dry season, which lasts from August to about April. When the rainy season comes on, the rivers are much swollen, and the logs are floated to the mouth of the river, where they are sorted and claimed by the various owners.

Many other very useful woods grow to perfection in this region, but have not yet found a place in the market.

South America.—This vast continent stretches from latitude 12° north to latitude 55° south, the area being approximately 6½ million square miles.

CLIMATE.—Owing to the extensive range of this country, all conceivable climatic conditions are experienced.

SOIL.—Extremely fertile.

RIVERS.—These are numerous, the principal being: *Magdalena, Orinoco, Amazon, La Plata, Colorado.*

FOREST AREAS AND TREES.—The whole of the northern area, including those areas drained by the Orinoco and Amazon, are to a great extent covered with virgin forests as yet unexplored. It is estimated that the area drained by the Amazon and its tributaries approaches 2½ million square miles, more than one-third the entire area of this continent. The length of this river is about 3500 ml., and, together with its tributaries, affords a waterway available for navigation for a distance of 50,000 ml.

1. *Venezuela* contains vast forests in the region of the Orinoco. At present these are of little commercial importance.

2. *British Guiana* has an area of 109,000 sq. ml., of which, it is said, 99 per cent is virgin forest.

The principal woods exported are: Logwood, greenheart, zebra wood, "hyawa holly" (*Omphalobium Lambertii*), lancewood, letterwood (*Brosmium Aubletii*).

3. *Brazil* has an area of nearly 3¼ million square miles, the greater part of which consists of virgin forests, which still remain unexplored. It is by far the largest forest area in the world. The chief timber trees are: Logwood (*Hæmatoxylon*), Brazilwood (*Cæsalpinia*), rosewood, and mahogany. Many others exist, but are not generally known or exploited.

4. *Para*, situated at the mouth of the Amazon, is the chief seat of the timber trade. British imports from this country, including timber, amount annually to about £4,000,000 sterling.

5. *Ecuador, Peru,* and *Bolivia* each contain extensive forests, but their woods are little known in the commercial world.

6. *Paraguay.*—The northern portion of this country is covered with forests producing a great variety of trees.

The extensive regions to the south of the continent are chiefly of a pastoral character.

ASIA

Space will not permit a full treatment of so vast an area, containing as it does practically one-third of the entire land surface of the globe.

The area is about 17,300,000 sq. ml.

CLIMATE.—There is a great diversity of climate, the vast continent falling as it does within three zones, i.e. frigid, temperate, torrid.

The vastness of its land surface and the arrangement of its mountain chains materially affect the climate in various regions.

FOREST AREAS AND TREES.—The surface is divided into seven distinct botanical regions, each producing its own characteristic vegetation, including forest trees of many varieties. The regions are known as Siberian, Tartarian, Cashmerian, Syrian, Himalayan, Indian, and Malayan.

1. *Siberian.*—The milder portion of this region is covered with enormous forests yielding various trees, as: Larch, birch, pine, &c.

2. *Tartarian.*—Very similar in character to the Siberian region. Along the slopes of the Himalayan range the following trees are met with: Pines, oaks, ash, birch, poplar, cypress, hazel, and Indian cedar (*Cedrela toona*).

3. *Cashmerian.*—The principal trees are walnut and chestnut.

4. *Syrian.*—For the most part this is a desolate region, producing few trees of importance.

5. *Himalayan.*—The trees of this region are for the most part dicotyledonous in character and are mainly deciduous. On the lower slopes are found extensive forests of saul and cotton trees of gigantic proportions. Ascending to the higher regions the climate is productive of such trees as pine, oak, elm, sycamore, hornbeam, whilst in the highest regions and extending to the snowline is found a great variety of oak, together with poplar, yew, sycamore, birch.

6. *Indian.*—This is by far the most important region for timber-producing purposes. It includes India, Burma, Siam, Cochin-China, and Ceylon.

There exist enormous forests, which are to a great extent swampy and exceedingly unhealthy, known as the "jungle".

The following are among the most important timbers yielded:—

Acacia, cedar (toona and deodar), coconut (*Cocos nucifera*), rosewood of

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India (*Dalbergia latifolia*), ebony (*Diospyros Ebenum*), calamander (*Diospyros hirsuta*), thingan (*Hopea odorata*), walnut (*Juglans regia*), ironwood (*Inga lucida*), satinwood.

Forests of Burma.—It is estimated that in Lower Burma alone the forest

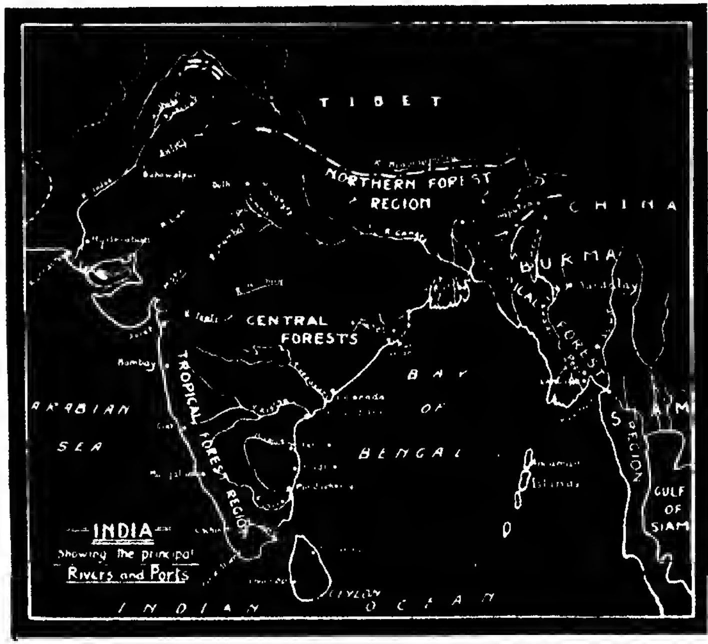

Fig. 105

regions cover 50,000 sq. ml., whilst the extent of the forests in Upper Burma is still unknown; they cover an enormous area of country. These forests are known chiefly for their teak, which is exported to all parts of the world. Over 200,000 tons of teak are taken from the forests annually; of which that exported amounts annually to about £500,000. Lower Burma supplies

about one-fifth of this quantity, the remainder being contributed by Upper Burma and the interior, and brought to the coast by means of the Rivers Irawadi, Sittang, and Salween.

Padouk is another important wood obtained from this district.

The elephant is the beast of burden used for carrying the trees from the interior of the forests to the streams. It also plays an important part in carrying out work in connection with the sawmills, such as carrying timber to the saws, pushing the logs through the mills, stacking and arranging the sawn planks. This work the elephants perform with an intelligence which is little short of human.

The principal ports engaged in the industry are Rangoon, at the mouth of the Irawadi, and Moulmein at the mouth of the Salween.

Ceylon contributes many ornamental woods to the market, but these are in most respects similar to those coming from the mainland.

Andaman Isles supply large quantities of padouk, also known as Andaman redwood. Convicts are largely employed in the work of clearing.

7. *Malayan.*—This region comprises the many islands situated under the equator. Camphor trees are the chief product of the forest, whilst the mountain regions produce certain varieties of oak and pine.

AFRICA

This vast continent has an area of about 12,000,000 sq. ml., practically one-fourth the land area of the globe. There is an unbroken coast line of 16,000 ml. Considering the enormous extent of the coast line there are but comparatively few ports.

Climate.—The greater part of this continent falls within the torrid zone, and the climate is exceedingly hot, and, in some parts, very dry. For the main part there are two seasons, a wet and a dry season, though little or no rain falls in the Sahara region, and but little in Egypt and the Eastern Sudan.

Soil.—A great portion is exceedingly barren, and it is only in those parts which are well watered that the soil can be cultivated.

Rivers.—Africa, compared with other countries, is very poorly supplied with rivers, and those there are do not serve as highways of commerce as in other countries, the current being either too rapid or impeded by rapids and cataracts.

Forest Areas and Trees.—The equatorial region and the south, where the rainfall is abundant, are well provided with forests containing valuable timber trees.

It is estimated that more than a million square miles are covered with forests producing, among others, such trees as acacia, ebony, ironwood, African teak, and mahogany. On some of the higher plateaux cone-bearing trees, as yew and junipers, are found. The equatorial forests abound in trees yielding rubber, which is of the finest quality known.

The central forest regions are: Upper and Lower Guinea, Senegambia, Sudan.

There are extensive forests in the south of Cape Colony (Knysna forest).

Cape Colony, Natal, Northern Transvaal.—The timber produced in this region is for the greater part exceedingly hard and tough, and is worked only

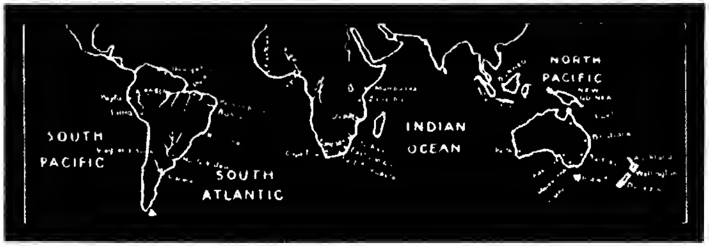

Fig. 106

with difficulty. It is apt to be very "shaky", and there is a great tendency to warp during seasoning. One great point in its favour is that it withstands the action of the dry climate better than most imported woods. With the attention and care now being given to the question of forestry by the Forestry Departments of the various provinces, much will be done to improve the quality of the timber produced in these areas.

The wood now produced is used chiefly for wagon and carriage building, also for cabinetmaking purposes. Among the most important are:—

Cape lancewood (assegai wood) or Cape ash, used chiefly for spokes, rails, and shafts.

Cedar boom, a fairly soft wood which will not stand exposure—used for floors.

Els (red, white, rock), wagon building.

Essen hout, yields valuable tough timber much resembling elm.

Ironwood (black and white), wagon axles, spokes, sleepers.

Melk hout (milkwood).

Oliven hout (wild olive), furniture, fittings.

Peer hout.

Suffraan hout.

Sneezewood, costly in working.

Stinkwood (Cape mahogany or walnut), for furniture, needs careful seasoning.

Geel hout (yellow wood), warps during seasoning and will not stand exposure.

Guinea Coast.—Timber does not form one of the exports of Africa, though many consider that valuable supplies will be derived from this source in the future.

OCEANIA

Oceania consists of three great groups of islands, known respectively as (*a*) Malaysia; (*b*) Australasia; (*c*) Polynesia.

AREA.—About 4,000,000 sq. ml.

Many of these islands yield valuable timber, those belonging to the Malaysian group being the camphor, sandalwood, ebony, teak, and upas.

POLYNESIA.—Sandalwood trees.

AUSTRALIA.—Australia produces many varieties of the eucalyptus tree, known as gumwood.

The district of Queensland produces some excellent woods for cabinet-making purposes, such as weeping myall, sandalwood, poison tree, broad-leaved cherry, tulipwood, huon pine, cedar (*Cedrela australis*).

NEW ZEALAND.—One of the most important trees in this area is the Kauri pine (*Dammara australis*). Red and silver birch, rata, black pine (*Podocarpus spicata*), are also found.

Methods of Transporting Timber.—These are many and varied. In mountainous regions the timber is usually cut and dragged to the mountain torrents, into which, after marking it, it is hurled and carried thence by the stream to the lower regions. Here again it is sorted and formed into rafts which float to the more distant parts.

Mountain chutes are sometimes constructed, consisting of tree trunks so arranged as to form a slide for the timber. In winter these are coated with ice, and the timber travels with an ever-increasing speed down the chute, until finally it dives into some lake or river.

In the Black Forest, on the smaller reaches of the Rhine, Rhone, and

Danube, single logs are floated down until they arrive at the broader parts of the stream, where they are made into small rafts, which continue their course, guided by men with poles. When the river again broadens out these smaller rafts are united into much larger rafts, usually occupied by a number of men constituting the "crew" necessary to the successful navigation of such a craft.

In Russia the trees are cut in winter and dragged by horses to the nearest stream which is covered with thick ice. The logs are firmly fixed together, and when the spring comes the ice melts and the rafts float down the various rivers to the ports.

In Australia the method adopted is to so arrange felled trunks that they serve as roads over which the logs can be dragged.

Note.—The above method of treating the subject of timber has been adopted as serving more useful purposes by opening up to the scholars the geography of the world in so far as it relates to manual training. As already explained, only the fringe of the subject can be touched in such a work. The subject becomes extremely interesting and fascinating when we study the life and habits of the people engaged in the timber-producing industries in all parts of the world.

The orthodox method of describing each separate wood in detail has been discarded as serving no useful purpose. The teacher who is keen on his subject will take an interest in collecting specimens of the various woods used for commercial purposes, and these are invaluable if properly handled, for by their means the scholars are enabled to ascertain for themselves all such information as relates to colour, weight, density, visibility of pore, visibility of annual rings, relative hardness, characteristic marking, &c., which is infinitely more important than volumes of such descriptive matter.

CHAPTER XIII

Metals used in Connection with Manual Training

During the various lessons it will be observed that nails and screws are made of iron; the various cutting tools are made of steel; the ferrules on the tools are made of brass. What are these substances and how are they obtained?

NOTES.

Iron.—The Ore—Iron is not found in a free state (pure). It is mixed with other substances of an earthy character, together with other elements which affect the quality of the iron produced. This mixture is known as *iron ore*. In order to separate the iron from the earthy substances it has first to be subjected to the process of roasting or calcining. This process merely consists of driving off all the water and gaseous substances (carbon dioxide) from the ore, and fits it for the next process.

Smelting.—The roasted ore is next packed into a furnace known as a *blast furnace* (see fig. 107). The contents of these furnaces are arranged in layers. A layer of fuel is first inserted, then a layer of roasted ore together with a substance which acts as a "flux" (lime or clay according to the composition of the ore), the object of the flux being to enable the earthy substance to fuse and flow freely when the heat is applied.

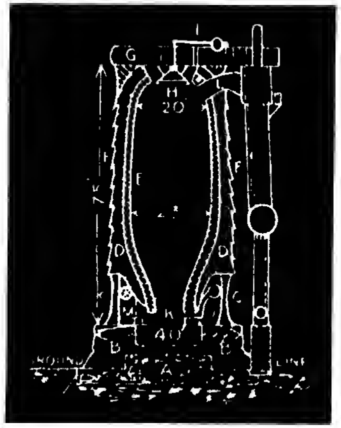

Fig. 107

The furnaces are fed by machinery with an extremely powerful blast of hot air, which causes the fuel to generate an enormous amount of heat, thus melting the contents of the furnace.

The fluid iron, being heavier than the earthy matter, sinks to the bottom of the furnace. Arrangements are provided by which the fluid earthy matter, known as *slag*, can be drawn off. At stated intervals the furnace is tapped and the molten iron is allowed to flow along channels in the floor, and fills moulds constructed for the purpose. The main channel is known as the *sow*, and the smaller moulds which lead off from the main channel are called *pigs*, and the blocks of iron cast are known as pig iron. The furnace is never allowed to cool down, but day and night fresh layers of roasted ore and fuel are added, and the process of drawing off the slag and tapping the iron is continued. The furnace is allowed to cool only when internal repairs become necessary.

Nature of Cast Iron.—Cast iron is very brittle in character. This will readily be seen if some article made of this material is subjected to

heavy blows from the hammer. The brittleness of cast iron is due to the fact that it contains carbon. It will assist in the understanding of this if the following experiment be performed.

Experiment.—Take a piece of cast iron and a piece of good wrought iron. Fix the piece of wrought iron in the vice and with a smooth file proceed to file its surface. Rub some of the filings on the hand and notice whether the hand is blackened.

Repeat the process with the piece of cast iron. Now we observe that the wrought iron filings left no mark, but that the cast iron blackens the hand like the dust from the lead of a pencil when it is sharpened. This blackness is due to the carbon which the iron contains, and it is carbon which causes the iron to be so brittle.

OBJECTS MANUFACTURED FROM CAST IRON.—It will be seen that some of the planes and the iron spokeshaves are manufactured from this type of iron; but during the process of manufacture some of the carbon is extracted, thus rendering them more malleable, that is, less susceptible to fracture when hammered, or less liable to break should they be dropped. But they are still brittle in character, and care must be exercised in their treatment.

WROUGHT IRON—*Experiment.*—Take a large nail and bend it backwards and forwards. Hammer the nail and show that it does not fracture. Compare with the effect of hammering or bending a piece of cast iron.

The nail thus possesses the properties of "malleability" and "ductility".

How are these produced?

Fig. 108

CONVERSION OF CAST IRON INTO WROUGHT IRON.—Since the brittleness of cast iron is due to the fact that it contains carbon, if we are to overcome this brittleness the carbon must be removed.

PUDDLING.—The carbon is removed in the following manner: The blocks of cast iron are placed in what is known as a reverberatory furnace, as shown in fig. 108. These furnaces are so arranged that the iron is not directly mixed with the fuel, but the heat is thrown down on the iron from the roof of the furnace; this is necessary to prevent the iron from absorbing carbon from the fuel. The iron is thus melted in a kind of pan.

When the iron is melted the workman in attendance takes an iron rod and, placing one end into the molten metal, commences stirring the iron,

and in this way masses of iron collect on the end of the rod which are called "blooms". These blooms are taken from the furnace and placed under powerful steam hammers and hammered into rectangular blocks, after which they are passed through rolling mills and thus rolled into bars.

This process is known as puddling, and by it practically all impurities, including the carbon, are removed. The bars of iron thus produced are known as wrought iron.

FAGGOTING.—The quality of the iron is still further improved by making up bundles of these bars (faggots), which are reheated and again hammered and rolled, thus giving to the iron its fibrous character and making it extremely tenacious, ductile, and malleable.

Experiment.—Fracture pieces of cast iron and wrought iron. Compare the crystalline nature of the fracture in cast iron with the fibrous appearance of the fracture in wrought iron.

WELDING.—A valuable feature of wrought iron is that two pieces can be joined by welding. The surfaces are heated to a state of fusion, they are then cleansed and brought quickly together and rapidly hammered, thus causing the fused surfaces to intermix and in this way to join.

Nails, screws, portions of the plane iron, and the grinding attachment are made of wrought iron.

Steel.—*Experiment.*—(*a*) Take a piece of cast iron, grind it thin and sharpen it in imitation of a chisel. Test it on a piece of wood and notice what happens.

(*b*) Repeat above, using for the experiment a piece of wrought iron. What happens?

Why do we not meet with these difficulties when using a chisel? Why does not the thin blade of the saw fracture or permanently bend out of shape? These are made of steel.

Conversion of Iron into Steel.—*Experiment.*—Take a piece of steel; fix it in the vice; using a smooth file, proceed to file the surface. Test the filings on the hand as was done with the cast iron and wrought iron. It will be found that it blackens the hand slightly, but not to the same extent as did the cast iron. Why is this?

Steel is a form of iron containing a small percentage of carbon, i.e. 1 to 1·2 per cent. The two chief methods for converting iron into steel are—

(*a*) From bars of wrought iron.

(*b*) From cast iron direct.

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(*a*) Wrought Iron to Steel.—The method employed is known as the "cementation process". It consists of placing bars of iron in a specially constructed furnace. Charcoal is laid between the layers of bars, and the whole covered in with charcoal. Heat is then gradually applied, and the temperature raised to about 1200° C., which temperature is maintained for about a week or ten days. This process causes the bars to absorb carbon from the charcoal (carbon) which surrounds them. When sufficient carbon has been absorbed—the amount varying according to the particular work for which the steel is intended—the quality of the bars being tested by taking trial bars from the furnace from time to time, the furnace is allowed to slowly cool down, the process of cooling taking about a week. When the furnace is cool the bars are removed, and it is then found that they are covered with a number of excrescences resembling blisters. The steel thus produced derives its name from this blister-like appearance, and is known as "blister steel". This form of steel is usually brittle. There is a want of uniformity in its structure, and it is somewhat crystalline in character. It is therefore again treated before being manufactured into articles of commerce.

Conversion of Blister Steel into "Shear Steel".—Bars of blister steel are bound together in bundles containing four or five bars. These are heated to a welding heat and subjected to a process of hammering and rolling, thus producing "shear steel". Should the process again be repeated it is then known as "double shear steel". From this steel the simpler cutting instruments, as knives, shears, scissors, &c., are manufactured. For the better class of cutting instruments the steel undergoes a further process, and is converted into "cast steel".

Conversion of Blister Steel into "Cast Steel".—To accomplish this bars of blister steel are broken in small pieces, placed in crucibles, and subjected to heat sufficient to melt the steel. The molten metal is then poured into moulds and afterwards hammered or rolled into bars. This process gives uniformity to the structure of the steel. From bars of this steel all the fine cutting instruments are produced, such as chisels, plane irons, saws, &c. It must be borne in mind that "cast steel" applies only to the method of producing the steel, and does not mean that the actual tools produced from it are cast to their particular shape.

(*b*) Conversion of Cast Iron direct to Steel.—This is usually accomplished by what is known as the Bessemer process, the resulting product being a mild form of steel now to a great extent taking the place of

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wrought and cast iron. Whilst it is not a form of steel with which we are particularly concerned from a manual-training point of view, yet it is of such great importance to the metal-working industries that a brief description will not be out of place.

THE BESSEMER PROCESS.—This process is carried out in a vessel called the "converter". The converter consists of a somewhat "bottle-shaped" vessel having the neck inclined to the body. It is constructed of iron lined inside with a fire-resisting material "ganister". The vessel is supported on trunnions resting on supports, and so arranged that the

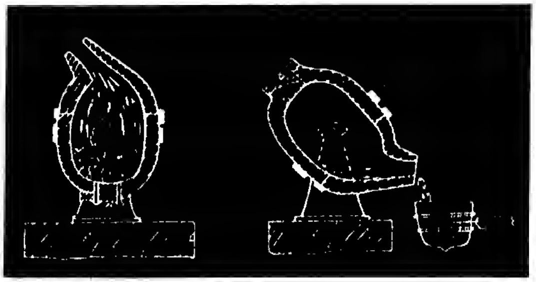

Fig. 109

vessel can be tilted to any angle. The bottom of the converter contains a number of holes, "tuyeres", through which air can be forced (fig. 109).

The iron to be treated is first melted in a cupola, or is led direct from the blast furnace into the open neck of the converter, which has been tilted over to receive the charge. The converter is then turned into an upright position and hot air forced through the molten metal in the interior. During this process enormous quantities of sparks and flame issue from the open end of the vessel. The oxygen contained in the air, as it passes through the metal, unites with the carbon and is thus driven off as carbon monoxide (CO). When the sparks cease to be given off, and the flame becomes less intense, the blast is shut off and the vessel again turned down and a definite quantity of molten iron rich in carbon, "spiegeleisen", is added.

The converter is again raised to the upright position and the added metal thoroughly mixed with the contents of the converter.

The converter is then turned down and the metal drawn off into ladles

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from which it is again poured into the various moulds, either for the purpose of castings direct or for forming blocks to be subsequently hammered and rolled into plates, bars, &c.

Properties of Steel.—We have seen that cast iron is hard and brittle, also that wrought iron is comparatively soft and ductile, neither metal being suitable for the manufacture of cutting instruments. Steel, however, possesses remarkable properties which enable it to be brought to any degree of hardness, at the same time retaining its toughness and flexibility. The process by which the desired degree of hardness is given to steel is known as "tempering".

Hardening and Tempering.—The tool having been forged and ground to the required shape is next hardened and tempered. In order to accomplish this the tool is first heated to a dull cherry-red colour and suddenly cooled by immersion in water or oil. This process causes the tool to become exceedingly hard and somewhat brittle. In this state it would be too hard for ordinary cutting instruments. The degree of hardness is reduced in the following manner.

The surface of the steel is made bright, and then subjected to a gentle heat which causes a film of colour to appear on the surface. The particular shade of colour assumed by this film indicates the degree of hardness which the steel will possess if cooled at that particular stage. When the desired shade of colour appears the tool is again cooled by immersion in water or oil, and is then ready for use.

The following table indicates the range of such colours:—

Colour of Film.	Temperature (F.).	Nature of Tools.
Very pale straw yellow ...	430°	Surgeons' lancets. Metal cutting tools.
Darker shade of yellow .	440°	Metal cutting tools and razors.
Darker straw colour	470°	Penknives.
Still darker straw colour ...	490°	Cold chisels, wood-boring bits.
Brownish yellow	500°	Plane irons, chisels, saws.
Yellow with purple tinge ..	520°	Stone-working tools.
Light purple	530°	Swords, watch springs.
Dark purple	550°	Tools for cutting sandstone.
Dark blue	570°	Small saws.
Pale blue	600°	Hand saws, pit saws, &c.
Pale blue with green tinge ..	630°	Try squares.

Brass.—AN ALLOY.—Brass is not a pure metal but consists of a mixture of two metals. The particular metals used are zinc and copper in the proportion of zinc (Zn) 1 part, copper (Cu) 2 parts by weight. When metals are mixed in this manner the resulting product is called an "alloy".

PREPARATION OF BRASS.—The metals to be mixed are carefully weighed in the above proportions. The copper is then cut into small pieces and made hot and placed in crucibles which are then inserted in the furnace. When the copper is thoroughly melted the zinc is carefully inserted, and as it melts it is stirred into the copper. When all is melted and thoroughly mixed the crucible is removed from the furnace and the contents run into moulds. Care has to be exercised during the process of inserting the zinc, as this metal is very volatile when in a molten condition.

Sheet brass is produced from the ingots by passing them between steel rollers. At each stage of the rolling the sheets are annealed.

ANNEALING consists of making the sheets hot and suddenly cooling them by plunging them into water.

Note.—Whilst this method softens copper and brass, it is worthy of note that the same process hardens steel.

BRASS POSSESSES MANY USEFUL QUALITIES.—(*a*) The well-known golden colour is pleasing and characteristic of this metal.

(*b*) It is harder than either of the metals of which it is composed, and therefore wears better than those metals.

(*c*) It is capable of receiving a very fine polish, and is less liable to become tarnished than copper.

(*d*) It does not rust (oxidize) when exposed to the action of water.

(*e*) It is very ductile, and can be beaten into any shape. The process of hammering causes it to become brittle. It therefore requires annealing from time to time.

(*f*) Brass cannot be welded, but the surfaces may be joined by solder, the solder in such cases consisting of a mixture of copper and zinc, having a lower melting-point than the metal to be joined.

Very delicate castings can be made in brass, owing to the fusibility of the metal.

Copper.—Copper, like iron, is usually found in the form of an ore, that is, the copper is mixed with other substances. This mixture takes various forms, as:—

Mixed with oxygen, known as red and black oxides of copper, and yielding from 80 to 88 per cent of copper.

Mixed with Sulphur and Earthy Matter.—This form is known as sulphide of copper and occurs in the form of "pyrites", yielding from 60 to 80 per cent of copper.

Mixed with Carbon and Earthy Matter.—These ores are especially beautiful in colour, varying from emerald green to deep blue. They are known respectively as (*a*) Green Malachite, (*b*) Blue Malachite, and yield from 50 to 60 per cent of copper.

Copper is sometimes found in a pure form. It is then known as "native copper". Large masses weighing many tons have been discovered in the United States of America.

Process of Extraction.—By reason of the various forms in which the ores occur, many different methods have to be adopted in keeping with the nature of the ore to be treated. Space will not permit of dealing with these processes fully. The main outlines of the process are as follows:—

1. *Calcining.*—For this purpose the ore is placed in reverberatory furnaces and roasted. During this process the ore is raked over from time to time, air is admitted, and in this way much of the sulphur and other impurities are got rid of. The amount usually treated is about 3 tons, which occupies about a day. This process is carried out at a low temperature.

2. *Melting the Ore.*—After roasting, the ore is mixed with other ores containing a considerable quantity of oxygen. The mixture is placed in another reverberatory furnace and subjected to a much higher temperature in order to melt the mixture. The molten copper sinks to the floor of the furnace, which slopes towards an outlet. When two or three charges have been thus treated the furnace is tapped and the molten copper allowed to drain out into a tank containing water. This causes it to assume a granulated form (small lumps). The metal thus obtained is still very impure, containing about 30 per cent of copper, the remainder consisting chiefly of iron and sulphur.

3. *Recalcining.*—The metal obtained from the last process is again placed in the furnace and roasted at a low temperature for about twenty-four hours. During this process some 50 per cent of the contained sulphur is driven off.

4. *Remelting.*—After roasting, the granulated metal is again mixed with rich oxides and the whole subjected to great heat. The molten metal is again drawn off. Sometimes it is cast into blocks, when it is known as "blue" metal, or it may be treated as before, i.e. granulated, when it is known as "fine" metal. The metal now contains 60 per cent of copper.

5. *Roasting and Fusion.*—The "fine" or "blue" metal is again roasted

and fused in specially constructed furnaces. Air is freely admitted into the furnace chamber. The process of melting occupies about eight hours. The slag which accumulates on the top of the metal is removed. The metal has a boiling appearance due to the escape of sulphur dioxide (SO_2), formed by the union of oxygen with the sulphur contained in the metal. When the process is complete, usually from twelve to twenty-four hours, the metal is again cast into blocks, which have a blistered appearance caused by the escaping SO_2. It is known in consequence as "blister copper", and contains about 98 per cent of copper.

6. *Refining and Toughening.*—Once again the blocks (pigs) of copper are placed in a furnace and slowly melted and the surface exposed to currents of air. Samples of the metal are taken from time to time during this process and tested. When the metal is found to be tough and malleable it is removed from the furnace with ladles and cast into ingots ready for the market.

Refer to characteristic colour of copper, its many properties, and uses to which applied. Copper costs approximately £70 per ton. Weighs approximately 550 lb. per cubic foot. Specific gravity 8·8.

Note.—The above process will serve to bring home to the scholars the difficulties involved and the expensive character of reclaiming copper from the ore. Much copper ore is found in South Africa, but owing to the cost of railway transit, shortage of coal in the regions where copper abounds, excessive cost of labour, and distance from seaports, it has not yet been found possible to work these ores profitably. With reduced working costs and the rapid development of electrical science this may at a future date become one of Africa's important industries. Many other valuable substances are found associated with copper, but these cannot be treated in this work.

Zinc.—THE ORE.—Like iron and copper, zinc too is found associated with other substances in the form of ore. These are known by different names according to their particular composition.

(*a*) Red zinc ore (spartalite).
(*b*) Calamine (carbonate of zinc).
(*c*) Blende (black jack or zinc sulphide).

EXTRACTION FROM THE ORE.—*Calcining.*—The ores are first roasted in a similar manner to that described for copper ore.

Distillation.—The roasted ore is crushed and mixed with anthracite (hard non-caking coal), small coke, and other substances. The mixture is damped and placed in specially constructed crucibles. These crucibles are stacked

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in a chamber connected with a furnace; they are arranged in tiers and slightly inclined. The lower end of the crucibles are fitted with a simple device for condensing the metallic vapours given off.

After packing the chamber, heat is applied to the crucibles and fumes of a brownish colour issue from the openings. These are succeeded by greenish-white flames. These flames are characteristic of zinc. The metal is collected from the condensers at intervals during the process, which occupies about twelve hours for each charge.

The metal is cast into ingots and is ready for the market or for further treatment.

Purposes Served.—Zinc resists the action of water, that is, it does not rust like iron. It is therefore used for coating iron in order to prevent it from rusting.

Articles manufactured from iron are coated with zinc. Care having been taken to see that such articles are thoroughly clean, they are then dipped into a bath of molten zinc. Examples of this will be found in the galvanized iron used for buildings, galvanized nails, linings of saucepans, &c.

We have already seen that when zinc is mixed with copper, brass is produced.

CHAPTER XIV

Notes of a Lesson on Glue, its Manufacture and Preparation for Use

Required for the Lesson.—

Cakes of glue, various kinds.
A few sweets, jellies, i.e. jujubes.
Cake of glue which has soaked in cold water for a considerable time.
A glue pot containing glue.
A glued joint, two pieces butt-jointed.
Pieces of wood; some porous, some dense.

Introduction.—Suppose we wished to join two pieces of wood together without using nails, or screws, or any "metallic" fastenings whatever, what substance could be used? "Glue"

COMPOSITION OF GLUE.—[Exhibit a cake of glue.] What is the name of this substance? Let us endeavour to find out what glue actually is.

[Exhibit some glue from the glue pot, which has been boiled and cooled into a jelly.] What is this?

You are all very fond of sweets. There is one class of sweet which you purchase which is soft and can be stretched. Name? Probably your mothers make nice jellies for dinner at times. From what substance are these jellies prepared? "Gelatine." [Explain: Glue is nothing more than a strong form of gelatine.] Would you like to eat this glue if it were made into a jelly? Why not? "Less pure than gelatine used for household purposes."

Substances Yielding Glue. When bones are boiled in the soup, what happens to the soup when it cools? What causes it to form into a jelly? Where did the necessary gelatine come from? Name a substance which is obtained from bones. If the bones of an animal contain gelatine, is it not reasonable to suppose that other parts also will contain gelatine?

You all like looking into a farrier's shop, to watch the man shoeing horses. What is the condition of the shoe when it is first placed on the horse's hoof? What have you noticed about the odour of the smoke given off? Burn a small piece of glue. Can you detect any similarity between the odours? Of what substance do you suppose the hoofs are composed? You have all seen the horns on a cow and on various other animals. Of what substance do you suppose they are composed? What might the horny parts of all animals be used for? "Manufacture of glue." [Explain: All animal refuse (offal) which contains gelatine may be used in the manufacture of glue.]

HOW MANUFACTURED.—What must be done to all this refuse in order to extract the gelatine, i.e. glue? [Elicit: "Boiled".] What must be done, besides boiling, to get rid of all the impurities, i.e. pieces of bone, lumps, &c.? "Strained." Examine the surface of this cake of glue. What do you notice about its surface? Of what does the shape of these marks remind you? "Wire netting." Are there marks on both sides of this cake? If this cake were laid on a piece of netting now, would the surface become marked? What must have been the condition of this cake when these marks were made? What reason can you suggest for laying the soft cakes of glue on the netting? "To dry." [Explain: Offal boiled in large boilers; liquid carefully strained off; pressed into large moulds; cut into cakes; laid on netting to dry. Exhibit various kinds; name them. English, French, Scotch, &c.]

GLUE ABSORBS MOISTURE—DOES NOT DISSOLVE.—[Exhibit some glue which has been in cold water for a number of hours.] What do you notice about this glue? [Elicit: "Soft, much swollen".] Suppose sugar or salt were placed in water for a number of hours, what would happen to it? Would it swell? [Elicit: "Dissolve".] What is the difference between glue "gelatine" and sugar in this respect? [Explain: Sign of inferiority if glue dissolves. When good it absorbs large quantities of water; swells very much, but does not dissolve.]

TESTING QUALITY.—[Allow boys to wet fingers and rub on surface of glue.] What is noticed? [Explain: Stickiness a good sign. Hold cake up to light, allow class to examine. Elicit: "Clear, but cannot be seen through". Explain: Not "transparent", but "opaque". Call attention to absence of spots, &c. This, also, a good sign.]

INFERIOR GLUE.—Glue that dissolves when placed in water, does not produce a

sticky surface when rubbed with wetted finger, and is inferior in quality, or if cloudy and containing specks or spots when looked through to light.

The Glue Pot.—[Exhibit glue pot to class. (Fig. 110.) How many parts are there? What does the inner pot contain? What the outer pot? The glue in the inner pot is stiff; how can it be made fluid? Suppose there was only one pot containing the glue, and it was put direct over the fire, what would happen? [Refer to piece of glue previously burned.] What is the object of having water in the outer pot?

Fig. 110

Preparation for Use.—What must be done to this cake in order to get it into the inner pot? [Elicit: "Broken into small pieces". Explain: Good plan to break into small pieces, cover with cold water, and leave it to soak for a number of hours before required for use.]

Test of Readiness for Use.—[Ask class whether they think it would answer to use the glue in the form of a very thick jelly, or thin like water? Exhibit glue ready for use, and let them see how that the glue just runs freely from the brush, and does not drop in lumps.]

Strength of Glued Joints.—[Have ready a short, well-dried glued joint. Endeavour to break it, thus demonstrating fact that the joint, if well made, is stronger than the wood itself. Call attention to weakness if too much glue be used.]

Adhesive Nature.—Let us endeavour to discover why it is that glue fastens two pieces of wood together. What have we discovered concerning the nature of glue? "Sticky." When two things stick together, they are said to "adhere" together.

Effect of Pores in Wood.—What did we discover to be the nature of wood? [Refer to occasion on which water was placed on wood.] "Porous." If water soaked into the pores of the wood, what can we conclude will happen when glue is placed on the wood? Could pieces of glass or iron be firmly "glued" together? Why not? "Absence of pores." Here are two pieces of wood [Exhibit specimens] one of which is soft, i.e. white pine, another very hard and close-grained, i.e. pitch pine. Which do you suppose will hold together best when glued, and why? "White pine softer, more porous; glue soaks in better."

Exclusion of Air.—[Explain: Close contact of fitting surfaces; glue causes exclusion of air between pieces; consequently the atmospheric pressure on pieces presses them together, and assists adhesive power of glue. Refer to experiment with wet leather sucker and string; rubber disk with hooks for attaching to glass in shops.]

BLACKBOARD NOTES

GLUE = *Strong Gelatine*

Manufactured from animal refuse containing gelatine.

Horns, hoofs, skins.
Boiled—Strained—Cut into slices—Dried on netting.

Kinds.—Numerous—English, French, Scotch, &c.
Test for Quality.—Swells when placed in water—insoluble.

Good.—Sticky if rubbed with wet finger—Clear—light—free from specks.
Inferior.—Dissolves in water—slimy feel—Cloudy—contains specks.

Glue Pot.—Inner pot—glue. Outer pot—water. Water prevents glue from burning.
Preparation for Use.—Broken into small pieces—soaked in cold water—boiled.
Ready for Use.—Run freely from brush—not thick—not thin.
Reasons for Holding.—Sticky nature—Pores in wood—Exclusion of air.
Good Joint.—Stronger than wood itself.

Make sectional sketch of glue pot on blackboard.

CHAPTER XV

Notes of Lessons on Screws and their Uses

Required for the Lessons.—

Sample screws of various types, sizes, and metals; an ordinary screw packet.

Call the attention of the class to various methods of fixing pieces of wood together, or fixing metal to wood, and the use of screws for such purposes.

DEFINITION.—The screw is a form of nail used for fixing pieces of wood together, or for fixing metal to wood.

THE HEAD AND SLOT.—Exhibit a common wood screw, preferably a large one. How are these screws made to enter the wood? What instrument is used for turning them? Where is the end of the screwdriver placed? "Slot." Where is the slot situated? "In the head." What is the shape of the head? "Conical." What must be done to the hole in which it is intended to place the screw in order to accommodate the conical head? Explain term "countersunk", hence heads of this particular shape are called "countersunk heads".

HEADS VARY IN SHAPE.—Refer to other shapes and exhibit specimens, as: "round headed", "gothic headed", "square headed".

BEARING SURFACE OF HEADS.—Call attention to difference between bearing surface on under side of heads, as: sloping in countersunk screws; flat

in round-headed and square-headed screws. Explain: square-headed screws, known as "coach screws".

Question concerning reason for this difference in the shape of the heads.

COUNTERSUNK HEADS.—These draw more easily into the wood and allow the heads to be turned in flush with the surface of the work. When used for metal the holes have to be countersunk to receive them. Ask scholars to mention examples of the use of such screws. Call attention to examples in room, if any, such as hinges (butts), locks, window fastenings, desks, &c.

ROUND-HEADED SCREWS.—These are used for ornamental purposes. Fixing *thin* metal to wood. Fixing locks, bolts, &c., where the projecting heads would not prove a disadvantage. Call attention to the danger of countersunk heads pulling through if countersunk into thin metal plates.

SQUARE-HEADED SCREWS.—Coach screws. Exhibit specimen. Refer to great strength and use for heavy work. Call attention to absence of slot. Why is this? Explain: The screwdriver is not strong enough to turn such screws, hence the heads are square in order that a "screw hammer" or "spanner" may be used. Call attention and demonstrate the greater leverage offered by such tools. In this connection it would be well to call attention to the leverage obtained by means of an ordinary screwdriver by virtue of its "pear-shaped" or elliptical handle. Long screwdrivers afford more leverage than short ones, owing to the fact that if the axis of the screwdriver be tilted slightly from the line of axis of the screw, the handle moves through a circle having a considerable radius, thus affording much more leverage than does a short screwdriver.

THE SHANK AND THREAD.—What is the shape of the top portion of the screw? "Cylindrical." How does the bottom portion differ from the top? What is the V-shaped ridge running round the lower portion called? Explain: "thread". Allow the scholars to examine the sharp edge of the thread, and compare it with an "engineer's screw", i.e. setscrew or bolt. Why is the thread so sharp? Why does the screw draw into the wood? In what direction does the thread pass round the screw? "Spiral." Allow the scholars to hold the threaded portion of a screw between the thumb and finger, and turn it round in order to understand the reason for this spiral twist.

Explain: The threads are cut by means of special lathes. If possible exhibit a "blank screw", also some of the turnings. Sometimes a blank and often small pieces of the turnings may be found in the packets of screws: these should be kept for the purpose of such lessons as the present.

PITCH OF THREAD.—Explain: The distance between the flanges is called

the "pitch". The pitch determines the rate of advance or entry. For every turn of the screw it advances a distance equal to the pitch.

THE POINT.—Call attention to sharp-pointed end. What is the advantage of the point? Demonstrate ease with which such screws enter soft wood. File the point off a screw, and demonstrate necessity for boring a hole the full depth of screw.

Compare old-fashioned, pointless screws with modern screws.

WHOLE OF SHANK NOT THREADED.—Question concerning the reason for not continuing the thread from point to head. This needs some explanation.

If screws were threaded for the full length of the shank they would advance through both pieces of wood at a uniform rate, and when the head reached its seating it would be impossible to further turn the screw. Should there be any space between the two pieces being fixed, this could not be closed, and the pieces would not draw together. By leaving the top portion of the screw blank it is possible to continue turning the screw though the head has reached its seating, thus the lower piece of wood continues to draw closer to the upper piece until the screw is quite tight.

DEMONSTRATIONS.—An ordinary bolt and two nuts will serve to show the uniform advance of the parts until the first nut reaches the head.

MADE OF DIFFERENT METALS.—Exhibit screws made of different metals as: Iron, brass, copper, iron galvanized. Question concerning the different metals used and reason for same.

Iron.—Ordinary work, protected from weather, or where rusting of screw is not objectionable.

Brass and Copper.—Ornamental work. Fixing brass or copper work. Situation exposed to damp, where the rusting of screw would be objectionable.

Galvanized Iron.—Work exposed to weather.

SIZE OF SCREWS.—Exhibit several screws of the same length, but having different "numbers". Call attention to difference in diameter. Refer to "number" on screw packets.

Exhibit screws differing in length but having the same number. Call attention to uniform diameter of each though length varies.

Explain: The size of a screw is indicated by its length and number. Higher numbers = greater diameter.

ADVANTAGE OVER COMMON NAILS.—Refer to method of driving nails and shocks occasioned thereby. Avoidance of shocks by use of screws.

Refer to necessity, in some cases, of frequently taking work to pieces, and the difficulty of doing so if nails be used.

Demonstrate the greater holding power of screws as compared with nails.

RIGHT AND WRONG DRIVING.—Screws should be turned in, not hammered. Show effect of hammering a screw into a piece of wood. This can be done by cramping two pieces of wood tightly together, and at the joint entering two screws, one driven in with a hammer as at A, the other turned in by means of a screwdriver as at B (fig. 111).

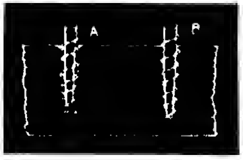

Fig. 111

Unscrew the cramp and separate the pieces. Call attention to ruptured condition of fibres at A; the cutting effect of flange at B.

"OVERTURNING" SCREWS.—Explain: Two evils likely to arise—(*a*) Screw becomes loose owing to the fibres of the wood surrounding the thread of screw becoming ruptured, i.e. broken and torn; (*b*) Danger of the heads being screwed off. These points serve the purpose of useful lessons in applied mechanics for more advanced classes. The following points should receive attention.

(*a*) Demonstrate lifting action of the "inclined plane" composing the spiral flange of screw. Show that it represents a thin wedge having a base equal to the periphery of the screw and an altitude equal to the pitch; that the wedge is driven forward with a force equal to the turning force exerted plus leverage of screwdriver; that the reaction of the flanges of the thread is at right angles to the surface of the thread; that the inclination of the plane being so slight such reaction is almost perpendicular, thus exerting sufficient force to rip or tear the fibres of the wood if they be soft. Further, that if the wood is hard, the same action takes place, but the fibres resist the tearing action of the flange. The head refuses to penetrate farther owing to hardness of the wood, the result of which is to set up an enormous amount of tension in the screw, which, together with the torsion set up, causes the screw to break at the top of the threaded portion.

(*b*) Explain action as in previous case. If the screws be "round-headed" the reaction on under side is perpendicular to the surface, and the heads are easily turned off.

DEMONSTRATION.—Where screws are made of brass the metal is brittle in character, and the absence of ductility enables the heads to be turned off with great ease. (*a*) Break a brass screw and examine fracture. (*b*) Turn

a brass screw into hard wood, and allow one of the scholars to twist the head off.

BLACKBOARD NOTES

A Screw.—A spiral form of nail.
Parts.—

- A. *Slot.*—Opening for screwdriver.
- B. *Head.*—Conical—Countersunk—Round heads—Square heads, &c.
- C. *Shank.*—Cylindrical forming lower part of screw.
- D. *Thread.*—Thin flange spirally arranged round shank—Cuts into wood—Causes screw to draw down—Gives great holding power.
- E. *Pitch.*—Distance between threads.
- F. *Point.*—Screws enter more easily.

Kinds.—Named after shape of head—Metal from which made.
Metals Used.—Iron—Brass—Copper.
Size indicated by length and "number".
Number indicates diameter of shank. Same number = same diameter for all lengths.
Advantage over Nails.—Less shock—Easily removed—Greater holding power.

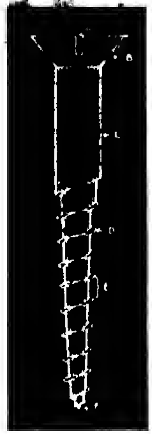

Fig. 112

Part II

PRACTICAL PRINCIPLES

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INTRODUCTION

The object of the present section being to bring together, in concise form, descriptions of the various tools used in the manual-training room, and as far as possible to describe the method of manipulating each as applied to a progressive course of exercises in woodworking, an endeavour has been made to indicate the lines upon which lessons on the various tools may be taken, in order to develop the scholars' powers of observation and reasoning. No hard-and-fast lines can be laid down for such lessons, however, and the individuality of the teacher must be brought into play.

The illustrations have been specially prepared in sketch form rather than direct from photographs, thus rendering them more capable of reproduction on the blackboard. Such sketches when reproduced on the blackboard are very striking, and readily impress themselves on the mind of the scholar.

In some cases blackboard notes of lessons are given. This has been done in order to show how the blackboard should be used for the purpose of summarizing the lessons.

It is a good plan for scholars to have notebooks in which such summaries may be entered, but unfortunately the time allotted to manual-training lessons does not always permit of this practice.

The lesson on "A Firmer Chisel and Comparison with Other Kinds" indicates in a general way the method of comparing and contrasting similar tools, and can readily be applied to other than those mentioned.

The lesson on "The Grindstone and Grinding" has been treated somewhat fully in order to indicate the method of questioning, with a view to making the scholars observe, think, and reason.

The underlying scientific principles and problems are dealt with in the chapter on "Science in Manual Training".

It is hoped that the present work will afford valuable assistance to technical students as well as teachers and scholars in the manual-training room.

CHAPTER I

Try Squares and Their Uses

Try squares are instruments used for testing the "squareness" of material, also for enabling lines to be drawn at right angles to any given surface.

CONSTRUCTION.—Try squares consist of two main parts—the stock and the blade.

A. *The Stock.*—This must be made of a hard tough wood that will not warp. Ebony and rosewood are chiefly used.

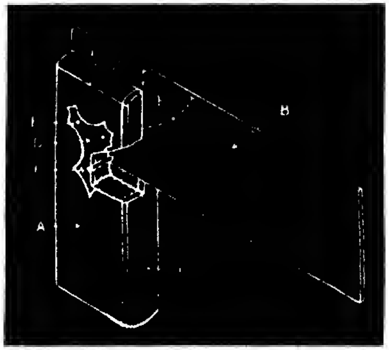

Fig. 113

The wood must be exceptionally well seasoned to prevent shrinkage and distortion.

The length of the stock varies according to the size of the square; while the two edge faces must be parallel to ensure true angles between the stock and the blade.

The working angles, of which there are three, as in fig. 113, *abc*, must be absolute right angles.

The angles are: (*a*) The right angle between the under edge of blade and face of stock; (*b*) the angle between the outer edge of blade and inner face of stock; (*c*) the angle between the outer edge of blade and outer face of stock.

B. *The Blade.*—This must be of steel and well tempered. The edges must be perfectly straight and parallel to ensure that both internal and external edges may be at right angles to the stock.

The edges of the blade are subjected to considerable wear, and when worn in the slightest degree alter the angle, as well as the straightness of lines

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made by their means. When worn, the edges must be refiled and angles made true, a somewhat difficult operation.

C. *A brass plate* covering the inner face of the stock. This surface is subjected to the greatest amount of wear, due to friction between the parts, when the instrument is in use. Brass wears more evenly and lasts longer than an unprotected wooden surface.

D. *Brass plates* are let in, one on either side of the stock as shown. Such plates are essential to prevent the rivets, used to fix the blade in position, from splitting the stock whilst they are being tightened (riveted), and also to prevent splitting should the square fall. The shape of the plate is of little importance, but is usually somewhat ornamental as shown. In the cheaper squares, three diamond-shaped pieces are used, as in fig. 114. These necessitate the use of less brass, but are not so effective as the former pattern.

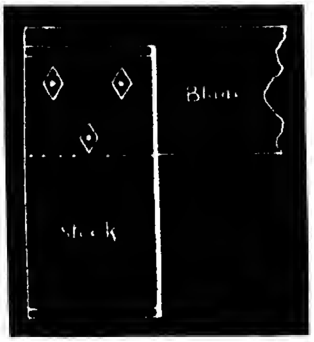

Fig. 114

E. *Rivets.* — The blade is fixed to the stock by means of three rivets.

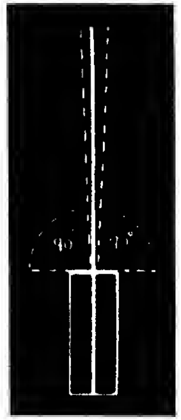

Fig. 115

It is essential that the blade should be in a plane perpendicular to the face of the stock (fig. 115).

All parts must be rigidly fixed together, and any looseness of parts is a sign of inferiority.

Dimension of Try Squares.—The size of a try square is indicated by stating the length of the blade, measured from the inner face of the stock to the outer end of the blade.

All other parts are in proportion, and have not to be stated when ordering.

The stock is usually about half the length of the blade, and the two most convenient sizes for manual-training purposes are $4\frac{1}{2}$ or 6 in. for small work,

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and 10½ or 12 in. for large work. The smaller of these dimensions will, in every case, be found to meet all requirements.

METHOD OF USING.—*For marking lines at right angles to working faces.*—It should be laid down as a rule that "*When in use the stock must always be against a working face of the material*", i.e. against the face side or face edge of the work. Fig. 116 shows the method of holding the try square in position. The thumb should press the stock against the face of the work. The first finger keeps the blade flat on the work. The remaining fingers are stretched across the work and clasp the back edge when the work is narrow, or grip, by friction, the surface of the wood should it happen to be too wide for the hand to stretch across.

Fig 116

The position of the hand will vary somewhat according to the position of the face marks on the wood, but little difficulty should be experienced if the two following rules are kept in mind: (*a*) Have the stock pointing to the *left*. (*b*) Always work with the stock on either the face side or face edge.

All lines should be drawn along the outer edge of the blade.

Fig 117

USE OF THE INNER ANGLE.—The chief use of the inner angle is for testing the squareness of the angle between two adjacent surfaces.

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This operation requires more care than is usually bestowed upon it. Fig. 117 shows in a general manner the method of performing this operation. The stock should be clasped easily but firmly between the tips of the thumb and fingers.

The stock must always be placed against a working face—the face side or face edge.

Fig. 118

The stock must stand perpendicular to the edge to be tested.

The blade must be held perpendicular to the surface tested from.

USE OF THE OUTER ANGLE.—This angle is often of service for testing the angle between the inner faces of a piece of work, as indicated in fig. 118.

TESTING A TRY SQUARE.—It has already been pointed out that it is essential that the angles of the try square should be true. They can be tested in the following manner: Prepare a piece of wood having a perfectly straight edge. Apply the try square to the edge and draw a line the full length of the blade; now turn the try square over and slide the blade up to the line already drawn. If the angles are true, the edge of the blade will coincide with the first mark; any deviation indicates an error. The principle underlying this can with advantage be demonstrated by means of a folding rule. Fig. 119 shows the two arms of the rule not at right angles, and the angle of deviation in consequence. If this deviation be halved, and the arms adjusted to the middle point, it will be found that they are at right angles.

Fig. 119

FURTHER USE OF THE BLADE.—It is often convenient to use the edge of the blade as a straight edge for drawing short lines which are inclined to the edge of the material. The extremities of such lines having been determined and marked by means of pencil, the blade of the try square

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may be applied and held by means of the thumb and fingers of the left hand as in position (fig. 120), the line being drawn by means of knife or pencil as desired.


Fig. 120

SPECIAL FORMS.—The angle of 45° is so often required that

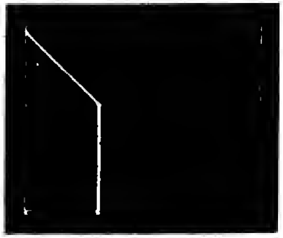
Fig. 121

provision is now often made for it in connection with the try square. This is done by making the top end of the stock at an angle of 45° with the inner face, as shown in fig. 121. Such squares are known by the name of "mitre squares". When used for marking such angles, the inclined face is applied to the work. Whilst being approximately true it will readily be seen that this inclined surface is too short to ensure great accuracy in working. Another disadvantage caused by removing the corner of the stock is the reduced support afforded to the blade, thereby increasing the tendency of the instrument to get out of order.

CHAPTER II

Gauges and Gauging

Gauges are instruments used for marking lines on the wood parallel to any working face.

For manual-training purposes three kinds are in general use: (1) The single-tooth marking gauge; (2) the mortise gauge; (3) the thumb gauge.

Single-tooth Marking Gauge.—This gauge is manufactured from various materials, as wood, iron, and combinations of wood, iron, and brass.

The principle underlying the construction is the same in each case.

There are four main parts, as shown in fig. 122.

A. *The stem or beam*, a piece of wood about 7 in. long, the section of which may vary in shape, but is usually made to the form shown in the sketch. Near one end a steel pin is passed through as at B.

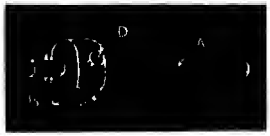

Fig. 122

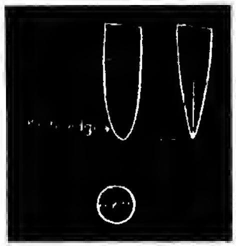

Fig. 123

B. *The Spur.*—The spur is of steel, and when bought is usually sharpened to a conical point. The spur should be so sharpened, as shown in fig. 123, to act as a cutter. The spur is driven through a hole in the stem, friction alone keeping it in position.

Fig. 124

The spur should be kept very sharp in order that it shall make fine cut lines and offer the least amount of resistance to the forward pressure when in use.

The spur is sharpened by means of a file, and when much worn can be driven farther through by means of a light tap with the hammer.

If the cutting portion of the spur is turned slightly, so that the plane of the blade forms a very acute angle with the face of the stock, as indicated at A B in fig. 124, it then has a tendency to draw farther on to the work, in this way tending to keep the stock close to the working face. This slightly increases the resistance to forward motion, but necessitates less effort to keep the stock in position against the face of the wood.

C. *The Stock.*—The stock consists of a block of wood through which a hole is made to receive the stem.

The face of the stock must be at right angles to the axis of the stem.

The stem, whilst fitting closely the hole in the stock, should be free to slide through the hole when pressed at either end.

The shape of the stock may vary. Three points have to be considered in its construction:—

1. *To give sufficient body of material to ensure rigidity, and to enable it to carry the screw which is used for fixing it in position on the stem.*

2. *The shape that will best suit the hand of the operator. For this reason the top is usually made semicircular, in order that the first finger may rest over the arch.*

3. *Protection of the face of the stock which, when in use, is in contact with the work; for this reason gauges have to be made of hard, close, and straight-grained woods, beechwood being most commonly used.*

The face is sometimes protected by means of two narrow bands of brass let into the face of the stock. In some cases the entire face of the stock is covered with brass, but this entails needless expense.

D. *The Thumbscrew.*—The stock is fixed in any desired position along the stem by means of a thumbscrew.

The screws being made of wood it is at once evident that the wood used must be exceptionally hard, or the "thread" would break away, hence boxwood is used for the purpose.

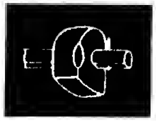

Fig. 126

The screw is usually placed in such a position that it faces the operator when the gauge is being used, and presents a serious obstacle to boys whose hands are small. For this reason it is better that the stock be taken off and reversed, thus overcoming the foregoing difficulty. A further advantage is obtained by filing a thumb slot in edges of the stock, as shown in fig. 125. The removal of the sharp edges of the stock is a great convenience where much gauging has to be performed.

Metal Marking Gauges.—Some marking gauges are now manufactured entirely of metal. Such gauges are less liable to get out of order. Being made of metal their dimensions must be kept small to ensure lightness, and the present forms are in this respect too small, which is a disadvantage.

The Mortise Gauge.—The chief use of this instrument, as its name implies, is for gauging the sides of mortises and also for gauging the corresponding tenons.

As will be seen in fig. 126 there are two spurs which can be separately

adjusted for relative position with the stock, thus enabling two lines to be made at any given distance apart, and at any required distance on from the face of the work.

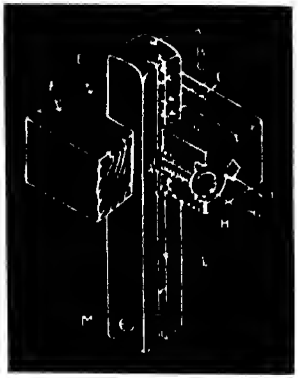

Fig. 126

CONSTRUCTION.—The construction is much more complicated than for the ordinary marking gauge, but the principle is the same.

The "wooden" stem or beam (A) is a piece of wood about 7 in. long and usually of square section.

The stem, and other wooden parts of mortise gauges are usually made of ebony or rosewood.

One surface of the stem has a T-shaped groove cut along the entire length, into which a bar of brass, having a corresponding section, is fitted (B).

A small portion of the bar about 1 in. long is cut off and rigidly screwed, as at C, to the wooden stem. Into this small piece one spur is fixed.

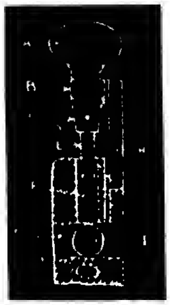

Fig. 127

The spur D is carried by the small piece of brass stem which is fixed to the wooden stem.

As already explained, the brass sliding stem has T-shaped section, the flanges of the T being inside the wooden stem, thus keeping the bar in position, and enabling it to slide freely along the wooden stem.

This bar also carries a spur fixed close to the end, where it fits against the smaller piece which is fixed to the wooden stem. When the two portions of the brass stem abut, the spurs are about $\frac{1}{8}$ in. apart.

At the bottom end of the sliding brass stem an enlarged flange is formed, through which a hole is made to receive a long thumbscrew, which is used for adjusting the sliding stem.

A brass thumb piece A, carrying an iron screw, passes through the flange B, and a hole is bored up through the centre of the wooden stem to receive it, as at F (fig. 127).

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At the end of the screw near to the thumb piece a collar is fixed to the screw as shown at D. Thus the screw is free to turn; at the same time its relative position to the sliding brass stem is not altered.

A small nut is inserted into the wooden stem as at I, about $1\frac{1}{2}$ in. from the bottom end. The position of the hole in this nut is made to coincide with the hole bored up through the stem. The thumbscrew, which is loosely attached to the sliding stem, passes through this nut, and when turned moves up or down accordingly, and owing to the loosely fitting collar already mentioned carries with it the sliding brass stem. Hence it will be seen that the distance between the two spurs is regulated by means of this screw.

The stock E consists of a block of wood through which a hole is made to receive the stem. The face is usually protected from excessive wear by means of strips of brass (as at F, fig. 126), or by a brass plate covering the entire face. It is fixed in position on the stem by means of an "iron set-screw".

The set-screw (G, fig. 126) being made of iron, and consequently having a much finer thread than would be used for a wooden screw, it is necessary that the screw should work in a metal nut "tapped", i.e. internally threaded, to receive it.

H is the brass nut for the set-screw.

I is an iron washer against which the set-screw works, and distributes the pressure of the small screw over a greater area.

J is a metal plate screwed to the stock, and forming a socket for the head of the set-screw.

An ordinary thumb-screw cannot be used for a mortise gauge owing to the fact that the screw has in this case not only to fix the stem to the stock, but also the brass stem to the wooden stem. The brass stem being on the under side, any thumb-screw in this position would consequently be inconvenient when working. Further, the gauge is, in the ordinary way, somewhat cumbersome, and the addition of a thumb-screw would tend to increase this.

It will be seen that ebony or other very hard wood is necessary in the construction owing to the friction between the stems, and the fact that the stem has to be bored to receive the adjusting screw.

Thumb Gauges.—The former gauges cut into the surface of the wood. In some cases this would prove a disadvantage, as in the marking out of chamfers or bevelled work. The difficulty is overcome by cutting a small piece of wood of rectangular section and making a notch at the end to lap

over the face of the work, as shown in fig. 128. The notch, or notches, can be made any length to suit the work in hand.

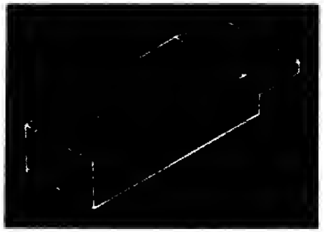

Fig. 128

Setting the Single Gauge.—It will be necessary to give a demonstration on the method of setting the gauge. The scholars should set their gauges stage by stage, the teacher giving the necessary instructions and demonstrating each, watching carefully to see that each step is correctly carried out.

The gauge should be held in the left hand, and, the screw being loosened, the stock can be moved along the stem by means of the end of the rule, or pushed forward with the thumb of the left hand, as shown in fig. 129. When the stock is in the desired position the screw should then be tightened. The distance between the stock and spur should again be tested to ensure that no movement has taken place. In the early lessons it is advisable that the teacher test all gauges after they have been set by the scholars.

Fig. 129

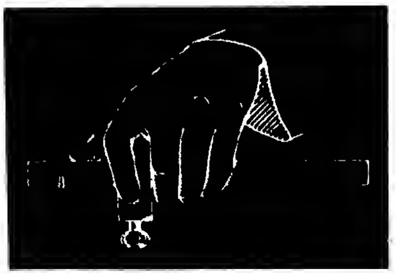

Fig. 130

Edge Gauging.—It will now be necessary to give a demonstration on the method of fixing the wood in the vice, the method of holding the gauge, and the pose of the body whilst gauging.

The wood should be fixed in the vice with the face side next the operator, i.e. outwards, and with the face edge uppermost.

The gauge should be held in the left hand, as in fig. 130, when it will be

seen that the thumb comes directly behind the spur, the first finger being arched over the stock, whilst the three last fingers clasp the stem.

Each scholar should stand behind his gauge and at arm's length from the work. The left foot should be extended well forward, the right extending backwards and slightly inclined to the side of the bench. The right hand should rest flat on the bench to support the weight of the body, and the left arm should be kept fairly straight. The gauge must be held firmly against the face side of the work, taking care to keep the stem at right angles to the face of the work. In order to advance the gauge it is necessary to press it in an oblique direction, as indicated in fig. 131. This has the effect of keeping the gauge up to the work and moving it forward.

To prevent "digging" into the wood the spur should slope slightly in the direction in which it is intended to draw the line. Fig. 132 shows the gauge sloping, whilst the arrow indicates the direction in which the gauge is moving.

Fig. 131

Fig. 132

A Common Mistake.—A mistake commonly made by beginners is that of ceasing to maintain the pressure upon the gauge when nearing the end of the work, the result being that the line is not parallel to the face of the work. This fault should be carefully pointed out during the demonstration.

Taken by Stages.—The first attempt on the part of the scholars should be taken stage by stage, the whole class executing each order as it is given. The following are the stages to be followed to ensure correct methods from the outset:—

1. Set the gauge as described, and place it on the bench near the vice, with the stem parallel to the side of the bench and pointing to the left.

2. Fix the wood in the vice, keeping it as high as possible and with the face marks turned towards the operator.

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3. All scholars should now be made to stand in position as described above.

Fig. 133

4. The scholars may now take up their gauges and place them in position with the spur on the end of the wood nearest them, sloping the top end of the spur away from them slightly (fig. 132).

5. Instructions may now be given for the scholars to gauge their line, reminding them of the direction in which to press the gauge. Teach them to go slowly and steadily.

There is usually much slovenliness in the matter of gauging, and bad habits once acquired are difficult to eradicate. Time is well spent in thoroughly mastering each detail in turn.

Fig. 134

Surface Gauging.—In this case the work cannot be fixed in the vice; other methods have, therefore, to be adopted.

The work should be held in the right hand, with the thumb on the end nearest the operator, and the remaining fingers stretching down the back edge of the material and forming a cradle in which the work rests. The bottom end of the work is pressed against the bench stop and kept in position by the pressure of the right thumb. The pressure on the gauge is resisted by the action of the first finger of the right hand, which rests against the back edge of the wood, and is in opposition to the force applied to the gauge. Fig. 133 indicates these positions in a general way.

The gauge is held in the left hand as for edge gauging, and when it has been advanced about halfway along the material the thumb of the right hand should be raised and the hand slid along the material, in this way clasping it about the centre. The material should then be removed from the bench stop to the side of the bench, and the line completed (fig. 134). Moving the work in this manner enables the line to be carried to the end without the screw coming in contact with the surface of the bench.

Setting the Mortise Gauge.—The width of a mortise is governed by the width of the mortise chisel to be used. The thickness of the tenon must correspond to the width of the mortise.

Having selected the particular chisel to be used, make a mark with the cutting edge on the piece of wood where the desired mortise is to be made (fig. 135). This mark indicates both width and position of the mortise, and the gauge must be set to it. Loosen the set-screw, and move the stock so that the fixed spur corresponds to the far end of the mark. Next, by means of the

Fig 135

Fig. 136

thumb-screw, adjust the sliding stem so that the spur corresponds to the near end of the mark.

Tighten the set-screw, thus fixing the stock in position. It is always advisable to make trial lines on an odd piece of wood, again testing them with the chisel. The corners of the chisel should come just to the centre of the gauge lines. This is important; for should the gauge be carelessly set it will not affect the chisel portion of the work, but the tenon, on being cut, will be either too thick or too thin; a serious error either way.

Fig. 137

Difficulties of the Mortise Gauge.—As the gauge is heavy and cumbersome it is advisable to fix the work in the vice whenever possible, and both hands may then be used in operating the gauge.

The left hand should occupy a position similar to that described for the single gauge, the right hand merely assisting in overcoming the resistance of the spurs.

Using the Thumb Gauge.—Having cut the notch to the required length, the gauge may be placed in position with a pencil resting against the end, as in fig. 137. Both gauge and pencil are then drawn towards the operator, as indicated in the figure.

CHAPTER III

Saws

CLASSIFICATION AND PRINCIPLES OF CONSTRUCTION

Definition.—Saws are instruments used for cutting wood, and have for their main object the production of clean-cut surfaces (flat or curved) with the least expenditure of material and energy.

Classification.—They may be divided into two classes: (*a*) Those used for producing plane surfaces; (*b*) those used for producing curved surfaces.

SAWS USED FOR PRODUCING PLANE SURFACES.—Many saws belong to this group, but only those required for manual-training purposes will here be dealt with. They are: (*a*) Rip saw; (*b*) hand saw, not often used; (*c*) panel saw; (*d*) tenon saw; (*e*) dovetail saw, not often used.

SAWS USED FOR PRODUCING CURVED SURFACES.—To this group belong: (*a*) Bow saw; (*b*) compass saw; (*c*) pad saw.

Construction.—FORMATION OF TEETH.—The construction of saws must depend upon the work they are required to perform. Most saws are required to act at a considerable depth from the surface; hence, whatever form of cutting edge is adopted, this edge must be supported, and the supporting body must be of such a character that it can follow the opening made by the cutting edge at starting.

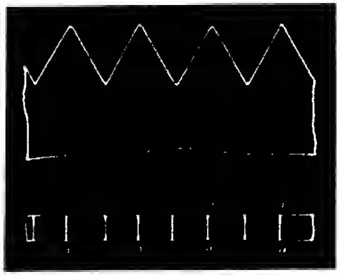

Fig. 138

It will readily be seen that a continuous cutting edge, such as a razor edge, will not serve to do the work as outlined in the above definition. Any instrument with a true cutting edge must of necessity carry a wedge-shaped supporting body, which would prevent it acting at any great distance below the surface.

When wedge-shaped cutting tools are used for cutting timber transversely, there is in consequence an enormous waste of energy and material, and the surfaces produced by their use are generally very irregular in character. The difficulty is overcome by the use of flat plates of steel, and the formation along one edge of a series of indentations. The indentations take the form of triangular recesses, with apex towards the plate, thus throwing a series of sharp points (teeth) into line with the edge of the plate.

In order to understand more clearly the cutting action of saws, it is necessary to study the character of the material to be cut. In the present instance that material is wood, and all wood is more or less fibrous in character. Again, much of the cutting takes place at right angles to the fibre, i.e. across the grain.

When forming the teeth, as described, if the triangular recesses be filed at right angles to the plane of the plate, this would form an edge at the apex of each triangle crossing the thickness of the plate at right angles, as at *a a* (fig. 138).

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Now we have seen that the wood is fibrous in character, and any attempt to cut across the fibres with such a saw would mean that, as the saw was thrust forward, the straight edge of each tooth would "burst" some of the fibres, as shown in fig. 139, causing them to splinter, but it would not remove them and give clearance for the blade. The loose fibres would act as valves, and when the saw was drawn back the valve-like action of the fibres would "grip" the saw and set up so much friction as would make it difficult to move the saw. How is this to be overcome? It is clear that the cutting must be of such a character that the fibres are removed for a length equal, at least, to the thickness of the saw plate. To do this the fibres must be cut in two places. This is accomplished by filing the teeth in such a manner that a double row of points is formed, the points being on the outer edges of the plate. This is illustrated in diagrammatic form in fig. 140,

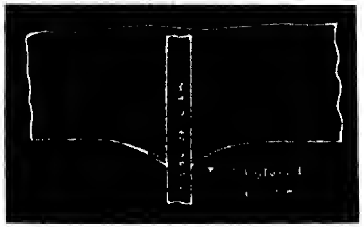

Fig. 139

Fig. 140

Fig. 141

a a a a being the points. Holding the file in the position necessary to form such teeth has the further advantage that the advancing edge of each tooth is formed into a "cutting edge" which materially assists the cutting action. Such teeth sever the fibres at two points, as at *a b* in fig. 141. The fibres forming the triangle above *a b* are caught in the triangular space, "the

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gullet", between each pair of teeth, carried forward and liberated outside the cut as "sawdust".

This is the underlying principle for all saws, but various modifications have to be adopted according to the special work each is intended to perform.

Teeth formed as above would make a cut (kerf) no wider than the thickness of the plate, and the friction on the sides would quickly prevent

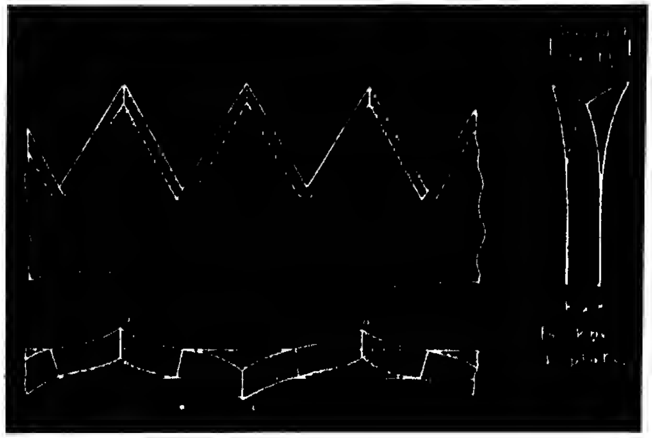

Fig. 142

the saw working. In order to overcome the friction and give greater clearance for the saw blade, the teeth are alternately bent outwards in opposite directions, as in fig. 142. This process is known as "setting" the teeth.

All saws are "set", but not to the same degree. The amount will vary with the nature of the work to be performed. Rip saws and dovetail saws require only a slight amount, whilst hand saws receive a considerable amount.

SAW HANDLES.—The handles are very important. They should be well shaped and fit the hand comfortably.

Too much care cannot be bestowed upon their finish. A badly finished handle is a source of annoyance whilst working with it, and leads to unsatisfactory work.

The handles are usually made of beech, but applewood is used for the better class of saw; handles made of this wood are much more pleasant to work with.

THE INCLINATION OF THE HANDLE.—It will be seen that the handles are in all cases inclined to the line of the teeth. When a saw is in use, pressure has to be exerted in two directions, namely forward, in order to advance the saw, and downward, in order that the saw shall enter the material. These forces would demand the use of both hands, or necessitate the exertion of leverage from the wrist, were it not that the principle of the "parallelogram of forces" can be applied. The dotted diagram at E, in fig. 147, will explain this principle. The force exerted at F, acting at right angles to the axis of the handle, is resolved into the rectangular components, owing to the teeth being in contact with the material, one force driving the saw forward whilst the other causes the saw to enter the material. The application of the "parallelogram of forces" thus relieves the wrist of any unnecessary exertion.

The Quality of Saws.—The quality of a saw depends upon many parts. (*a*) *Temper of Blade.*—The blade should be thin, and when tested by bending it should curve uniformly, returning again to its original form when released. Any permanent curvature due to bending indicates a soft, improperly tempered plate. Thick blades usually indicate inferiority.

The blade should be hard. Such blades necessitate more care in the setting, and take longer to sharpen, but they have the advantage of retaining their cutting power for a longer period and work more sweetly.

Well-tempered saws are usually somewhat dark in colour and the surface has a greasy appearance.

(*b*) *Grinding.*—The surface of the plate should be free from hammer marks, and the grinding should be uniform: any inequalities can be detected by holding the blade up to the light at arm's length whilst examining the surface.

The blade should be thinner at the back edge than it is at the cutting edge, thus affording more clearance in the kerf when in action and necessitating less "set".

When struck, the blade should give a clear, bell-like "ring", any dull sound is a probable indication that the blade has a "flaw" fracture. A further test for fracture is to hold the saw firmly in both hands by the handle and cause the blade to oscillate from its fixing in the handle—a fractured blade will give out a "cracked" sound.

(*c*) *Handles.*—The handle should be well finished and fit the hand com-

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fortably. It should be held in the hand in the correct position for working, in order to test the "hang" of the blade.

It should be firmly fixed to the blade by means of saw rivets, as any looseness in this respect is likely to cause the blade to "buckle" when in use. The rivets should be flush with the surface of the handle.

DESCRIPTION AND SPECIAL USE

(*a*) **The Rip Saw.**—The rip saw is specially constructed for cutting in the direction of the grain "fibres". The teeth are large and shaped as in fig. 143.

Fig. 143

The "pitch" of the teeth, i.e. the inclination of the advancing edge of each tooth, is about 80°.

When sawing in the direction of the fibres less friction is generated, consequently these saws need very little "set".

The cutting action of rip saws varies somewhat from most other saws. As already explained, the teeth are formed into edges rather than points with the result that when in action each tooth acts after the fashion of a plane or chisel, removing a shaving each time it is thrust forward.

Fig. 144

(*b*) **Hand Saws.**—Hand saws are specially constructed for cutting across the grain, but they are generally used for cutting both with and across the grain. The details of the teeth are shown in fig. 144.

The teeth are formed into sharp points at the apex, and the front edge of each tooth is inclined to the line of advance in such a manner that the outer edge has a chisel-like action when in use.

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The general character of the work performed by this saw demands that the teeth shall receive more set than is given to most other saws.

(*c*) **Panel Saws.**—Panel saws are used chiefly for cross-grain cutting, where clean cuts and absence of splintering on the under side of the material are desirable.

Fig. 145

They have usually eight teeth to the inch, and the "pitch" is shown in the accompanying figure (145).

The teeth are formed in the manner described for those of the hand saw.

These saws are used for finer work and require less set than hand saws.

(*d*) **The Tenon Saw.**—The tenon saw is used chiefly in connection with bench work and for making the finer cuts. The name is derived from the fact that one of its chief uses is that of cutting the shoulders of tenons, the shoulders being the cross-grain cuts at the base of the tenon, which have to fit the plane surface of the material surrounding the mortise. This being the case it is clear that the surface produced by the saw must be flat and as smooth as possible. The saws already described have no stiffening rib, and consequently are free to bend; further, their great length and cumbersome character unfits them for use in cutting small or delicate shoulders. Examination of a tenon saw will at once make clear its special advantages for the character of work indicated.

Fig. 146

The blades are rectangular in shape, varying in length from 10 to 18 in., and from 3 to 4 in. in depth; they are much thinner than blades of the "hand-saw" class. The lack of stiffness due to use of small thin plates is compensated for by the introduction of a "stiffening rib" or "back", which is folded along the top edge of the plate. These "ribs" are made of brass

for the better class of saws, but steel is often used in inferior types. The blade of the saw should not reach the top of the curve inside the "fold", but is gripped tightly along the edges. The back should also be slightly arched, being higher in the centre than at the ends, which gives a spring-like action to the rib; the pull of the ends sets up tension along the cutting edge, thus tending to keep that edge straight.

Fig. 147

The depth of cut which can be made with a tenon saw is limited owing to the use of the stiffening rib.

The teeth are small, varying from 10 to 14 per inch.

The advancing edge of each tooth is inclined at about 65° to the line of the teeth, as in fig. 146.

The handle of the tenon saw varies in design from that of the hand-saw group. The necessity for this will readily be understood when it is borne

Fig. 147 a

in mind that the tenon saw is in most cases used in a horizontal position, whilst hand saws when in use are invariably inclined.

There are two types of handles: (*a*) The closed handle, as in fig 147; (*b*) the open handle, as in fig. 147*a*.

The former is much stronger than the latter, and has usually a higher degree of finish.

The open handles are short in the grain, and are apt to split along the line A B, as seen in fig. 147*a*.

(*e*) **The Dovetail Saw.**—This is seldom to be met with in the manual-training room, a fine tenon saw being suitable for practically all the work executed therein.

The special features of this type of saw are: (*a*) Very thin blade; (*b*) very fine teeth; (*c*) little or no set on the teeth.

Dovetail saws are usually smaller than the tenon saw, but in all other respects are similar to them. The smallest variety has usually a straight handle in line with the back.

Saws used for Producing Curved Edges.—The nature of the work such saws are intended to perform demands that they shall have narrow blades, in order that they may pass freely round a "quick", i.e. sharp, curve.

With the narrowing of the blade comes the attendant weakness and tendency to bend and buckle when in use. This difficulty has been to some extent overcome by inserting the blade in a frame, as in the case of the bow saw.

Fig. 148

The Bow Saw.—This is by far the most important saw for cutting fine and sharp curves.

The details are shown in the accompanying figure 148. The frame consists of five main parts. A A are the two arms or "levers" of the frame; B

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is the beam which keeps the two arms apart. The ends of the beam are stump-tenoned into the arms A. Each end of the beam acts as a "fulcrum" about which the arms are free to turn, as at X. At C are several strands of string forming a loose loop about the ends of the arms A. Through the loop so formed another lever D is inserted for tightening the string. When turned, the lever twists the string into a sort of rope, which at every turn becomes contracted in length, thus pulling the top end of the arms A A closer together, whilst the lower ends become extended, due to the rotation of the arms about X X.

Through the lower end of the arms are cylinders of brass (F F), which are slotted to receive the ends of the saw blade. Holes are also drilled through these cylinders at right angles to the slots which receive the saw blade. The saw blades are drilled, the holes corresponding with those in the cylinder, thus enabling the saw to be fixed in position by means of two steel pins G G. The brass cylinders, after passing through the frame, enter the handles, into which they are riveted. Forming part of each cylinder, and situated immediately outside the frame, are enlarged flanges; these flanges take the strain due to the tension set up in the saw by the contraction of the string.

The saw blade, being fixed in "cylindrical" piece, can be turned to any convenient angle to accommodate the work in hand.

The frame of the saw is usually made of beechwood, the handles being of boxwood. The more common varieties have their handles made of beechwood, but it will readily be seen that these are less suitable for holding the rivets used in connection with the brass cylinders.

The Compass Saw.—These saws are used for making curved cuts in larger work where it would be impossible for the body of the work to pass through the opening in the frame of a bow saw.

Fig. 149

Fig. 149 shows the general construction. They are made in various sizes. It will be seen that they much resemble the hand saw. The blades taper to a point and are kept as narrow as possible consistent with the work they are intended to perform. The narrowing of the blade is attended with consequent weakness, and in order to overcome this weakness the blades are made much thicker than those of ordinary saws.

The increased thickness of the plate demands increased energy when in use —the energy in all cases being proportioned to the amount of kerf and the nature of the material to be cut.

The formation and general arrangement of the teeth should be as described for the panel saw.

The Pad Saw.—These saws are very useful when small holes have to be cut, or for cutting sharp curves where even the blade of the compass saw would prove to be too wide to enable it to pass round the curve.

Fig. 150 shows the general construction.

A is a wooden handle, usually of boxwood—sometimes of rosewood or ebony. It is shaped in such a manner that it will comfortably fit the hand

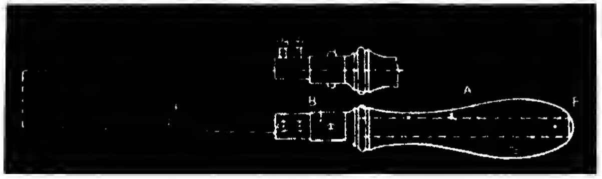

Fig. 150

at whatever angle the blade may be turned. B is a specially constructed brass ferrule attached to the handle by means of small screws, and C contains a slot through which the saw blade passes. At D are set-screws for fixing the blade in position. Two are required to keep the blade steady. E is the blade. This is constructed on the principle of the panel saw, but with teeth formed more after the order of the tenon saw. The blades are very narrow and thin, and consequently lack strength.

A hole passes through the handle, as indicated at F; this enables the saw to be moved backward and forward as desired, according to the work in hand. When not in use the blade can be passed into the handle, thus protecting it from injury.

METHODS OF SAWING

Physical Development accompanying Sawing.—It is very important that the correct pose of the body be studied when performing sawing operations.

NOTES

Sawing exercises are valuable for physical development, and it is essential that the teacher pay special attention to all the details connected therewith.

Ripping on the Trestles.—This operation applies to the sawing of long planks upon the sawing trestles. The plank, having been "lined out", is allowed to rest on the trestles with one end projecting about 9 or 12 in. It is kept in position by placing the right knee upon the plank immediately behind and in line with the saw, as in fig. 151. The saw must be held in a plane at right angles to the surface of the plank and coincident with the line to be cut. In order to ensure that the saw is held in a plane at right angles to the surface of the plank the head should be in a position immediately over the saw, thus enabling the operator to watch the angle on each side of the blade. Should the head be inclined to right or left the saw is invariably pulled to that side towards which the head inclines.

Fig 151

The arm should be in a direct line with the saw blade, and all strokes should be taken freely from the shoulder, giving full expansion to the chest.

The cutting edge of the saw should be inclined at about 70° to the surface of the plank, but this of course will depend greatly upon the height of the operator. There is a tendency with small boys to lower the saw to a very acute angle. Such a position is uncomfortable for the boys and has the additional disadvantage of making the "surface of contact" very much greater. The greater the angle which the teeth make with the surface of the plank the less will be the "surface of contact", but when the angle is increased beyond 70° the position again becomes uncomfortable.

Ripping at the Vice.—When short pieces have to be ripped it is more convenient to fix the wood in the vice, and the panel saw is generally used for this purpose.

NOTES

The general position of the body is shown in fig. 152.

The left foot is extended forward. The right foot falls about 15 in. to the rear and is slightly inclined, thus giving stability to the body.

The wood is steadied by means of the left hand. The saw and arm should be in line, the body occupying such a position that the elbow of the right arm can swing freely as a pendulum without coming in contact with the body.

The head should be held fairly erect and in such a position that it commands a view of the angles made by the blade of the saw and surface of the wood. The strokes should be long and taken freely from the elbow and shoulder. It is not necessary to throw the weight of the body into the action. The chest should be freely expanded with each stroke.

Fig. 152

The Tenon Saw.—A large amount of work is performed by this saw, and the method of using it needs to be carefully taught. Considerable time should be spent on this when executing the first exercise, and the work should be taken by stages, as:

(*a*) *Fixing the Work.*—The bench hook is first fixed in the vice, or hooked to the side of the bench, and the work placed in position against the stop.

(*b*) *Position of the Left Hand.*—The work is steadied by means of the left hand. It should occupy a position as in fig. 153, in which it will be seen that the work is pressed against the stop by means of the palm of the hand whilst the thumb is extended to the far end of the line to be sawn, thus serving to guide the tip of the saw when starting the strokes.

(*c*) *The Right Hand.*—The saw is held in the right hand. Three fingers are passed through the opening, whilst the first is extended along the handle, pointing towards the tip of the saw; this serves to steady and guide the saw. The arm should be in a direct line with the saw.

(*d*) *The Feet and Body.*—The left foot is extended forward at right angles to the bench, whilst the right foot drops to the rear and is inclined to the bench. The body should not occupy a crouched or cramped position;

it should be kept clear of the right elbow in order that the upper part of the arm may pass freely backward and forward, keeping in the direct line of the saw.

(e) *The Head.*—The head should be kept erect in such a position that it can easily be seen whether the saw is perpendicular to the surface of the work or not.

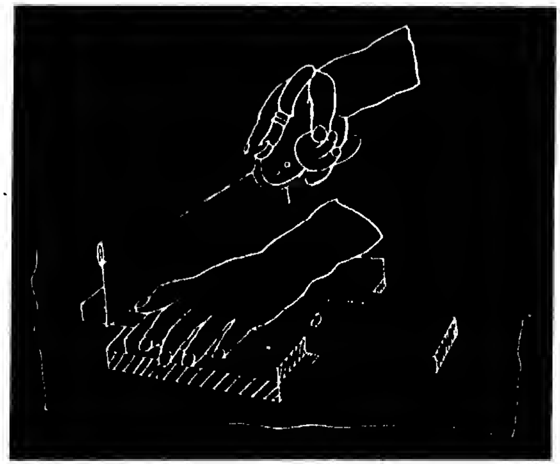

Fig 153

The Stroke.—When starting the cut, the tip of the saw should be used, the teeth being inclined to the surface as in fig. 153. As the saw is advanced the handle is gradually lowered, care being taken to follow the line to be sawn. When all the surface fibres have been cut, the saw should be maintained in a horizontal position. Having severed the surface fibres a groove is formed which serves to guide the saw in the "cross" direction; more attention should then be given to keeping the saw upright.

The strokes should be long, thus employing all the teeth. Very little force is required; the weight of the saw, together with the force acting on the inclined handle, being sufficient. All movements should be performed with ease. Should the body occupy a cramped position, or the effort to saw be too laboured, bad sawing will inevitably result.

The Work Staged.—The importance of this class of sawing cannot be too strongly emphasized. In dealing with new classes it will be found wise to take the different steps simultaneously throughout the whole class. Having given the necessary demonstration and carefully pointed out all the points needing attention, instruct the class to carry out the work in the following stages:—

1. Fix bench hook and wood in position.
2. Stand in position. Recapitulate each step as previously demonstrated.
3. Take up saw and stand ready for cutting. The teacher should now examine the position of each scholar, correcting the many little errors which he is sure to find.
4. Commence sawing; go slowly; do not force the saw; heads erect; watch gauge marks.

These stages should be repeated as each cut is made. This will do much to ensure correct method from the outset; later, greater freedom can be given to the scholars, always assuming the operations to be correctly performed.

Oblique Sawing.—This needs no special description. The body should be ranged in line with the cut to be made. More care is necessary when starting the saw, owing to its tendency to slide along the fibres.

Sawing with the Grain.—The tenon saw is often used for cutting the sides of small tenons.

Fig. 154

The tip of the saw should be placed on the farther edge of the wood at starting (fig. 154), the cutting edge being lowered gradually until a cut has been made entirely across the piece. When this is done the tip of the saw is allowed to go no deeper, but the handle is gradually lowered at each successive stroke until the teeth are in the line of a diagonal of the face of the tenon to be cut. The material is then turned and cut from the other side. It is not necessary when making the second portion of the cut to adopt the diagonal method. The kerf made on the first edge forms sufficient guide for the saw on the unseen edge, the operator merely allowing the saw to work freely in the kerf and following carefully the line on the seen edge.

NOTES

The Bow Saw.—When in use the large handle is held in the right hand whilst the two first fingers are hooked round the inner portion of the frame, as shown in fig. 155. The thrust is given by means of the right hand, the saw being drawn back by means of the left.

Care should be taken to see that the blade is kept perpendicular to the surface of the work.

When making sharp turns it is essential that the reciprocating motion of the saw be continued during the turning process; neglect of this precaution leads to broken saw blades.

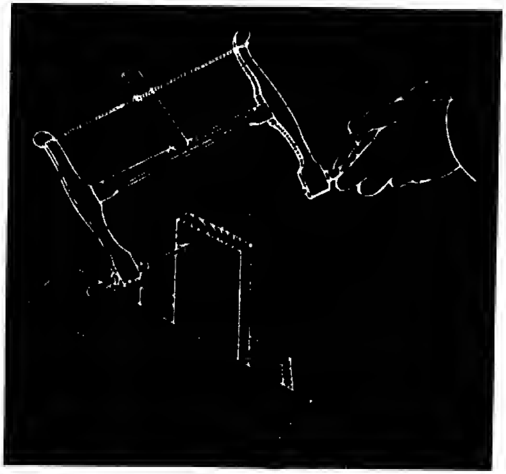

Fig. 155

The Compass Saw.—The use of this saw needs no special description. Both hands are generally applied to the saw.

The blades being wide, much friction is generated during the passage of the saw round sharp curves, causing the saw to become very hot. It is therefore advisable to oil or grease it frequently.

Setting and Sharpening.—Saws need to be kept in good condition if satisfactory work is to be done, and a brief account of the method of doing so will not be out of place.

(*a*) *Alignment of Teeth.*—When a saw requires sharpening the first point needing attention is the alignment of the teeth. In the larger type the line of teeth should form a slightly convex curve from handle to tip. In order to bring the top of the teeth into line they are run off by means of a flat smooth file. The file should be held by its edges between the thumb and finger of the right hand, and, starting from the handle of the saw, the file should be run along the top of the teeth once or twice to ensure all teeth being in line. This should not be overdone, as it must be remembered that

the teeth have again to be filed up to sharp points and any needless rubbing down increases the labour involved to say nothing of wasting the saw plate.

(b) *Setting.*—The teeth should next be set. Professional saw setters accomplish this by means of specially constructed hammers and anvils, each tooth receiving one blow sufficient to produce the required amount of bending. All blows must be uniform, an operation requiring great skill.

It is the custom now to use one of the many specially constructed appliances for this purpose. The principle of construction involved is a combined punch and anvil, with screw attachments to regulate each in keeping with the size of the teeth to be set.

Whatever method be adopted it is essential to bear in mind that the bending must be in the tooth itself, and principally at the top. Any attempt to bend the tooth below its base causes the teeth to fracture and distorts the plate. There is greater danger in this respect when using the patent saw sets than if the hammer and anvil method be adopted. The set must be uniform on both sides, otherwise the saw, when in use, will tend to curve towards that side on which the teeth have most set.

Amount of Set.—This depends entirely upon the work which the saw has to perform.

Saws for cutting dry seasoned wood require less set than those used for cutting wet or unseasoned wood; for cutting hard wood, less than those used for soft woods; for cutting in the direction of the fibre, less than for cutting across the fibre.

The main object is to afford just sufficient clearance in the saw "kerf" to enable the saw to work easily, and any undue amount of set involves waste of material, increases the labour involved, and makes it more difficult to keep the saw running true.

Filing the Teeth.—The shape of the teeth was dealt with when speaking of the construction (see p. 157).

The shape will of course depend upon the particular angle at which the file is held. In all cases the handle of the file is lowered and turned in the direction of the tip of the saw.

Having determined the required angle at which to hold the file, care must be taken to maintain this angle for all the teeth.

The filing takes place from both sides of the blade, in order to form the cutting edges to the front of each tooth. Every alternate "gullet" on one side is first filed; the saw is then turned and the intervening "gullets" similarly dealt with.

Rip-saw Teeth.—For these the file should be held almost at right angles to the blade, thus forming more of a chisel edge than of a point at the top edge of the tooth.

Fixing the Saw.—The blade of the saw should be rigidly fixed in a vice, and the teeth should be in line with the elbow when the elbow is raised for filing. The position should be such that a good light falls upon the teeth in order that the operator may see when each tooth is sharp. This is indicated by the fact that light is no longer reflected from the top surface of the tooth which was flattened by the "rubbing down" process.

The cutting action of the file must be uniform on both edges of the teeth forming the particular gullet being filed, otherwise the size of the teeth will vary.

The file strokes should be uniform throughout, the finishing strokes being light in order to avoid formation of "burr" on the outside of the teeth and any undue bending of the point.

Filing must cease immediately the tooth has been brought to the point. Should the filing be continued after the point is formed, the "true line" of points will be destroyed and the work of cutting will not be evenly distributed.

CHAPTER IV

Planes and Planing

Planes are instruments used for removing the surface of wood and reducing it to any desired shape or form.

They may be classified in three groups:

(*a*) Those used for producing plane surfaces.
(*b*) Those used for producing concave or convex surfaces.
(*c*) Those used for producing mouldings.

General Description.—Planes consist of two main parts. In all cases there is a cutting iron, and this is supported by means of a body, known as the "stock". The stock, in addition to acting as a support for the cutting iron, enables the action of the cutter to be controlled, and the under surface serves, in some cases, as a pattern of the surface it is desired to produce.

Reasons for Planing.—When the wood leaves the saw, the surfaces are in a rough state, showing the marks of the saw. The surfaces are often twisted, especially if the timber has been cut a considerable time, and the dimensions and shape of the wood may not be such as are desired.

When pieces of wood have to be carefully fitted together it is necessary that each piece be made true in order that the various joints can be accurately marked for cutting.

The reasons for planing which commonly apply to manual training may be summarized as follows:—

1. To produce plane surfaces.
2. To obtain the required angle between adjacent surfaces.
3. To reduce the wood to the required dimensions and shape, if the work be not plane surfaced.
4. To produce smooth surfaces.

It is important that in any such scheme the production of smooth surfaces be placed last, because it is so easy to produce "smooth surfaces" and yet ignore all the more important details of dimensions and angles.

The success of a piece of work is largely dependent upon the quality of the planing, and when a scholar has been taught to plane accurately there need be little fear concerning the quality of his finished work. Teachers are well advised to pay particular attention to this point.

Planes used for Producing Plane Surfaces.—To this class many planes belong, but for manual-training purposes the following will suffice: (*a*) The jack plane; (*b*) the trying plane; (*c*) the smoothing plane; (*d*) the rebate plane; (*e*) the routers.

The Jack Plane.—Jack planes are used for removing the rough surface of the wood and making it approximately true. They are also used for reducing the dimensions where much material has to be removed.

CONSTRUCTION.—The construction of the jack plane being typical of most planes, it is here dealt with somewhat fully, thus avoiding the necessity for treating all such planes in detail.

Jack planes are usually made of wood, beech being most suitable for the purpose, although many of them are now manufactured entirely of iron.

Beech is used in their manufacture for the following reasons: (*a*) It is a hard, close-grained, compact wood; (*b*) it is uniform in texture; (*c*) it retains its shape well when it is thoroughly seasoned; (*d*) it is sufficiently dense to give the required weight; (*e*) the surface wears well and uniformly; (*f*) the wood is plentiful, hence it is reasonably cheap.

A. *The Stock.*—Usually about 16 in. long by 2¾ to 3¼ in. square, according to the width of the iron.

The stock is subdivided into many minor parts: (*a*) *The tip or nose*: The front end of the plane. (*b*) *The heel*: The back end of the plane. (*c*) *The face or sole*: The under surface. (*d*) *The mouth*: The opening in the face through which the shavings enter. (*e*) *The escapement*: The opening in the top surface through which the shavings escape. (*f*) *The bed*: The inclined surface upon which the cutting iron rests. (*g*) *A slot in the bed*: To receive the head of the screw which is used for fixing the two portions of the cutting iron together.

The stock also has let into it:—

B. *The Handle or Toat.*—This is made of beech and let into the stock for about ¾ in.

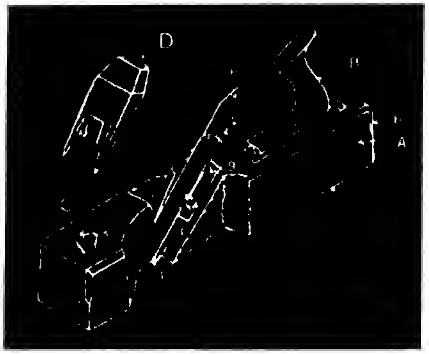

Fig. 156

The grain of the wood is very short, and any carelessness in handling the plane will often cause it to break across, the two chief causes of fracture being: (*a*) Dropping the plane; (*b*) holding the plane by the handle whilst delivering the blows to liberate the iron. This is a common fault with boys, and should be carefully guarded against. The correct method of performing this operation will be explained later.

C. *A Button.*—A raised piece of very hard wood (usually boxwood) which receives the blows from the mallet which are delivered when separating the iron from the stock. The button being raised, and consisting of hard wood, prevents damage being done to the plane by the repeated blows from the hammer or mallet. It can easily be renewed when worn, and is let into the stock for a distance of about ¾ in.

D. *The wedge* is made of beech. It serves to fix the cutting iron in position, and fits into carefully prepared grooves in the sides of the escapement. The fitting of the wedge is important.

The following faults will arise from misfitting wedges: (*a*) The cutting iron "chatters", i.e. vibrates and produces uneven cutting; (*b*) the shavings

force their way between the wedge and iron and cause the plane to "choke up", i.e. the mouth becomes stopped with shavings which cannot pass through; which necessitates taking the plane to pieces and "re-setting" it. The difficulty constantly recurs until the cause has been removed. The wedge is forked, as in sketch, to give clearance in the centre for the shavings. A notch has also to be made in the back to enable it to pass over the "back nut" on the cap iron, thus allowing the wedge to bed firmly on to the iron, the pressure being in this manner uniformly distributed.

THE IRONS.—The accompanying sketch (fig. 157) shows the details of construction.


Fig. 157

The Cutting Iron.—This consists of (*a*) a blade of iron with (*b*) a steel face welded on its upper surface, the steel face being continued as far as the slot, as indicated by shading in fig. 157.

(*c*) The width of the cutting-iron determines the size of the plane, the usual size being 2¼ in.; for manual training 2-in. jack planes are as heavy as can be managed by boys.

(*d*) A slot having an enlargement at one end through which the head of the screw passes which is used for fixing the "cap or back iron" to the cutting-iron. The various bevels applying to the cutting-iron are shown at the side in fig. 157.

(*e*) *The Grinding Bevel.*—When the irons are ground the surface made by the grindstone should make approximately an angle of 25° with the face of the iron.

(*f*) *The Sharpening Bevel.*—When sharpening the irons on the oilstone the face of the iron should make approximately an angle of 35° with the surface of the stone.

(*g*) *Angle of Clearance.*—When in position in the stock the iron is "pitched" at an angle of 45°, i.e. the angle which the "bed" makes with the "face" or "sole" of the plane.

It will thus be seen that there is a difference of 10°, which enables the sharp cutting edge to freely enter the wood. If no clearance be given the sharpened surface slides over the wood, but no cutting takes place. This error is sometimes due to faulty sharpening, which often happens with beginners, who, in their eagerness to "sharpen the iron quickly" elevate it to too great an angle.

NOTES

Taper of Irons.—It will be seen that the cutting iron is much thinner at the top than at the cutting end. When the plane is purchased the opening at the mouth is very fine—narrow, but as the iron is ground from time to time, this opening becomes larger, so large, in fact, that it is often necessary to let a piece of wood into the face of the plane in order to reduce the width of the opening, as in fig. 158. These pieces are about ½ in. thick, and must be very carefully fitted. This operation is known as "remouthing".

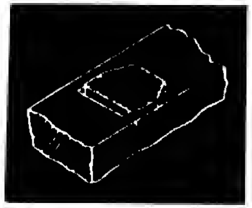

Fig. 158

Parallel Irons or Gauged Irons.—In order to avoid the necessity for "remouthing", plane irons are now manufactured which are uniform in thickness throughout. Repeated grinding does not, therefore, affect the opening at the mouth. These irons are slightly more costly, but prove more economical in the end. The mouth being kept fine enables more accurate work to be executed.

The Cap or Back Iron.—(*a*) These are made of steel and are curved as shown in fig. 159. The object of the curve is to enable the front edge *b* to fit exactly and tightly to the surface of the cutting iron Any misfitting along this edge allows the shavings to pass between the two irons, thus causing the plane to "choke up". Once the edge "beds", i.e. fits properly, it should on no account be interfered with.

c a brass back nut, riveted into the iron to receive the screw.

Fig. 159

d is a setscrew having a large "pan-shaped" head, the under side of which is flat in order that it shall fit the surface of the cutting iron.

It will now be seen that when the cap iron is in position on the cutting iron the edges *b* and *c* are in contact with it, and the screw on being tightened causes these edges to fit more closely and so firmly as to prevent any movement between them when in use.

Use of the Cap Iron.—The cap iron serves to regulate the action of the cutting iron. Assuming the wood to be slightly cross grained and apt to "tear up", if the edge of the cap iron be set close up to the cutting edge the effect is to hold the shaving down whilst the under surface is exposed to the action of the cutting edge, thus cutting beneath the rising shaving

before it has had an opportunity of splitting below the line of action of the cutting iron (fig. 160).

When the wood is "straight grained" the cap iron is of little service in this respect and can be kept farther from the cutting edge, about $\frac{1}{16}$ to $\frac{1}{8}$ in.

Fig. 160

The cap iron has the further advantage of stiffening the thin cutting edge, thus preventing "chattering", which, if it occurs, causes the surface of the work to assume a "ridgy" or "wavy" appearance.

CONDITION OF CUTTING EDGE.—It is necessary that the cutting edge should be kept sharp, whatever be the kind of plane used. Blunt edges entail more labour and produce unsatisfactory work, and it is no "saving of time" to work with a blunt plane rather than spend time in sharpening the iron.

Fig. 161

SHAPE OF EDGE.—Considering that the jack plane is used for the rougher portions of the work it is advisable that the cutting edge should be curved as in fig. 161. It will be seen that when in use such an edge will form a series of hollows and ridges running in the direction of the length of the material. These ridges are afterwards removed by the "trying plane", the cutting iron of which has a straight edge, except for a very slight amount of rounding at the ends which prevents the corners from "digging" into the wood and leaving sharp ridges.

The Trying Plane.—This plane is much larger than the jack plane, being about 22 in. in length and about $3\frac{1}{4}$ to $3\frac{1}{2}$ in. in section.

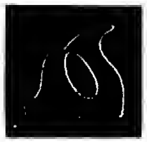

Fig. 162

It is now manufactured in three different forms, as: (*a*) All wood (beechwood); (*b*) All iron, except handles; (*c*) Combinations of wood and iron.

CONSTRUCTION.—The construction varies very little from that of the jack plane.

Owing to the greater weight of the instrument it is necessary to provide for greater strength in the handle. This is secured by closing the handles, as shown in fig. 162, the front portion acting as a strut or stay.

The "face" or "sole" must be kept very true, and the mouth should be kept very fine—"narrow". Parallel or gauged irons are of great assistance in this direction.

As already explained, the cutting edge must be very straight.

USE OF TRYING PLANES.—They are used for "finishing" the surface of material after it has been made approximately true by the use of the jack plane.

SHOOTING.—"Making straight" the edges of boards which have to be "jointed" together.

The shortness of the jack plane and "roundness" of cutting edge leaves many slight inequalities of surface, which are readily discovered by the trying plane with its greater face area and straight cutting edge.

The plane should be "set" very fine, the thickness of the shaving being about $\frac{1}{100}$ part of an inch, the width being little short of the full width of the iron.

The Smoothing Plane.—This is a small plane used for cleaning and smoothing off the work after it has been brought to the desired shape and size.

The details of construction are much the same as for the jack plane.

The plane being very short, no handle is provided, but the body is made narrower at front and back and all corners rounded off in order that it may be clasped in the hands, as shown in fig. 163.

Fig. 163

ADVANTAGE OF THE SMOOTHING PLANE.—When planes are in use the pressure exerted by the operator is of necessity distributed over an area equal to that of the face of the plane. When "cleaning off" or smoothing a piece of work it is often found that certain parts are more "cross grained" than others, these parts being more liable to tear up. The smoothing plane, being small, enables the full amount of pressure to be concentrated on such parts, the cap iron being set much closer to the cutting edge, and the plane itself being set finer enables such difficulties to be overcome.

Another advantage will be found in the ease with which this plane can be manipulated.

Rebate Planes.—These are narrow planes (fig. 164) so arranged that the cutting iron extends across the full width of the stock, thus enabling

a shaving to be taken off which is the full width of the stock. They are used for forming "rebates", i.e. rectangular recesses along the edge of a piece of wood.

CONSTRUCTION.—The construction varies from the foregoing.

The mouth extends across the full width of the sole so that the escapement must be formed in a different manner to that previously described.

The cutting iron is made parallel for a distance of about 2 in., then it is recessed on both sides and continued by a central shank, as in fig. 165. The central shank passes through a mortise in the stock which is sufficiently large and so shaped as to receive a wedge for fixing the iron in position.

Fig. 164

Fig. 165

The escapement has therefore to be formed on the side of the stock. It takes the form of a splayed circular opening having the larger side towards the operator and on the "off side" of the rebate when the plane is in use.

No cap iron is used with this plane. In order to compensate for this deficiency and enable the plane to produce smooth surfaces the irons are placed on the "skew". This also has the further advantage of casting the shavings towards the escapement.

In the commoner variety of planes the irons are placed "square", but these seldom work sweetly and are always liable to "choke up".

Router Planes.—These planes are used for planing the bottom surface of a groove, or any surrounded sinking into which it would be impossible to get any other form of plane. They also serve to regulate the depth of such sinkings. The best form is constructed of iron with screw attachments

to enable the depth of the cutter to be regulated. Routers are often improvised in wood by mortising through a block of hard wood and inserting the blade of a chisel, or a plough iron (fig. 166). Wooden routers, by reason of the high pitch at which the iron must be inserted, do not act so well as iron ones, which by reason of the special formation of the cutter, can have the pitch so reduced as to produce the best effect when cutting (fig. 166*a*).

Fig. 166

Fig. 166a

Planes used for Producing Concave or Convex Surfaces. — SPOKESHAVES.—These are instruments used for planing curved surfaces and edges.

Two forms are in general use: (*a*) The wooden spokeshave; (*b*) The iron spokeshave.

WOODEN SPOKESHAVES — CONSTRUCTION.–Spokeshaves consist of a number of parts much as in the case of the jack plane, but special modifications have to be made in view of the nature of the work which they have to perform (fig. 167).

Fig. 167

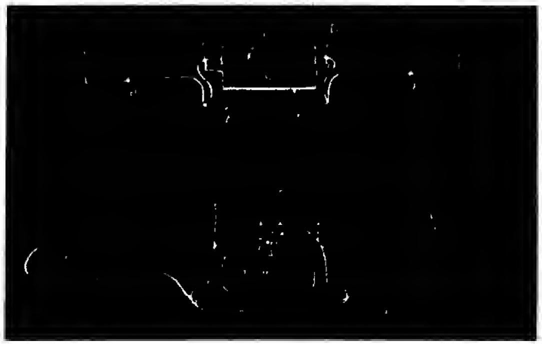

Fig. 168

A. *The Stock.*—In the best spokeshaves the stock is made of boxwood, whilst beechwood is used for the inferior kinds.

The under surface, corresponding to the sole of a plane, is somewhat rounded in order to enable the instrument to pass freely round "quick"—small radii—hollow curves.

The stock is sometimes faced with brass to preserve the surface.

B. *The handles* are arranged in continuation of the stock and shaped out to an elliptical section to afford a firmer grip.

C. *The Blade or Cutting Iron.*—This is made of cast steel, the ends being turned up at right angles to the cutter to form "tangs", by means of which the iron is held in position in the stock.

The inner face of the iron is hollow ground.

When sharpened, a narrow stone "oilstone slip" is used, and this rests across the hollow, touching both front and back edges.

D. *The Tangs.*—These are pyramidal in shape, and pass through the stock. They are held in position by friction alone. The position of the iron is regulated by tapping the tangs backward or forward, as desired, with a hammer. There is great danger of fracturing the iron whilst doing this unless great care be exercised.

E. *The mouth* is the opening in the face or sole by means of which the shavings enter.

The amount of cut is regulated by means of the tangs, which, if driven forward, increase the opening at the mouth and the thickness of the shavings.

F. *The Escapement.*—This is an opening for the escape of the shavings.

IRON SPOKESHAVES.—Iron spokeshaves are now largely used. The construction of the stock is much the same as for those of wood.

The main difference is in the arrangement of the cutting iron, which is made on the principle of an ordinary plane iron, and is held in position by means of a screw. The cutting action of the iron is adjusted by means of the front portion of the stock, which, in the better kinds, is arranged on pivots and actuated by means of springs, the adjustment being regulated by means of a thumbscrew, as in fig. 168.

Other forms are made having double irons, i.e. a cap iron.

Iron spokeshaves have usually a much flatter face or sole than wooden spokeshaves, hence they are not so suitable as the latter for sharp concave curves.

They are very liable to be fractured if allowed to fall.

SIZE OF SPOKESHAVES.—This is determined by the length of the cutting edges, the most convenient size being 2 or 2½ in.

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Planing Processes.—The reasons for planing and the importance of correct planing have already been stated. The various operations will now be described.

SURFACE PLANING.—The material when it leaves the saw is rough and often slightly twisted, in addition to being too large. These errors are corrected by planing, and the first operation consists of preparing a "face side". For this purpose the piece of timber is carefully examined and the

Fig. 170

Fig. 169

best surface selected. It is then tested for "flatness". This can be done in either of the following ways:—

(a) *Small Pieces.*—The piece of wood is held in the left hand, and by means of a straightedge the surface is tested for straightness in all directions, i.e. diagonally and across the piece.

Should the surface be flat the straightedge will fit in any position, any error, such as a twisted surface, "warped", or curvature being at once apparent, because the straightedge does not fit the surface. (See fig. 169).

(b) *Large Pieces.*—Unless a long straightedge be used it is clear that the foregoing method cannot conveniently be applied. Even should this be possible, slight errors in flatness would be difficult to detect. In such cases the following method is adopted.

Two pieces of hard wood, usually about 16 in. by 2 in. by ½ in., and having their edges perfectly parallel, are prepared, technically known as "winding battens or strips". The piece of wood is laid flat on the bench and the winding strips are placed across the surface, one at each end of the plank to be examined. The operator then takes up such a position that the eye is in line with the edges of the battens, and any error can at once be detected. If the plank is flat, i.e. a plane surface, the battens can be moved into various positions along the plank, but on looking across their edges they will appear always in the same straight line or parallel (fig. 170).

Sometimes two jack planes are laid on their sides across the material in the manner described; these are cumbersome, and serve but as a rough test.

Having made a careful survey of the surface, the planing may now be started.

Holding the Jack Plane.—The handle or tool of the plane is gripped

Fig. 171

firmly in the right hand, the first finger being extended to the wedge. The left hand is placed over the front end of the plane (nose), the thumb being on the near side of the plane and the fingers on the off side, as shown in fig. 171.

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The fore end only of the plane should rest on the material at starting, and pressure should be exerted by the left hand, and as the plane advances the pressure with the left hand is slightly reduced and that of the right hand increased.

POSITION OF THE BODY.—The operator should occupy a position well behind the plane, in order that the action may be that of direct pushing along the line of resistance. Beginners often stand to the side of the plane, and consequently much of the energy exerted is lost. The feet should be slightly apart, the left foot being advanced and nearly parallel with the side of the bench, whilst the right foot is practically at right angles to the bench (fig. 172).

Fig. 172

When taking the stroke, there should be free movement of the knees, elbows, and shoulders, the motion being similar to that of lunging.

REMOVING THE HIGH PARTS.—Unless the surface is already flat the plane should not be allowed to take continuous strokes throughout the length of the piece, but its action must be confined to first removing the high parts, be they corners, ends, or middle of the plank. When these errors have been approximately corrected the strokes may then be taken with greater freedom, and should pass freely from end to end of the piece, the surface being frequently tested by means of the straightedge or winding strips.

Use of Trying Plane.—For manual-training purposes, and small work generally, the jack plane is usually sufficient for finishing the surface, but for large work it is necessary to introduce the "trying plane". The surface of the plank is treated in the manner already described, and when all roughness has been removed, and the surface made approximately true, the jack plane then gives place to the trying plane, which, not having to execute any rough work, can be kept in much better condition. The mouth is much finer (narrower opening), and the cutting edge of the iron should be practically straight, for the reason already described. Trying planes, as we have seen, are considerably longer than jack planes, and thus ensure greater accuracy in the straightness of the surface.

The method of holding is similar to that described for the jack plane.

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Little or no pressure on the plane is required, the increased weight being all that is necessary. The plane is merely guided over the surface, and of itself finds any high portions and first removes these. When the surface is true, the plane should with ease remove a fine shaving from end to end of the plank.

MARKING THE FACE SIDE.—When a surface has been made true it is marked with a mark known as the "face mark", the surface being known as the "face side" (fig. 173). Except under special conditions the mark should always point to the best edge of the material. This is at times varied when the working of a moulding along an edge has to be considered, the mark being then arranged in such a manner that when working the moulding the plane operates in the "direction of the grain".

Fig. 173

PLANING A FACE EDGE.—Having completed the face side, the next operation is to plane the best edge, i.e. that edge to which the face mark points. If the piece of wood is thick, and will rest firmly upon its edge on the bench, it may be placed in a position similar to that for surface planing, and the operation of planing proceeded with. Winding strips are not required for the edge, but the surface must be made straight and at right angles to the face side, the surface being frequently tested by means of the straightedge and try square. The try square should be always used with its stock against the "face side", a precaution which beginners frequently overlook.

THIN MATERIAL.—When the material is too thin to rest on the bench as described it must then be fixed in the vice, which necessitates a modification in the method of holding the plane with the left hand. The plane needs to be carefully guided along the narrow edge. This is accomplished by placing the thumb on the nose of the plane (or the button), the hand and fingers being extended down the near side in order that the finger tips may touch the surface of the work and so guide the plane and maintain its balance (see fig. 174).

Before commencing to plane the surface, it should be tested by the aid of straightedge and try square, for inaccuracies, and these parts should first receive attention. Should the material be hollow the ends must first be

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planed, care being taken to remove a uniform amount from each end except in the case of material which may happen to be slightly narrow at one end, in which case the bulk of the material would be removed from the wide end. Should the surface be convex in the length, the planing should then be commenced at the highest part of the curve and successive shavings removed, each being longer than the former, until the surface has been made straight.

When inaccuracies occur in the squareness of the edge, the plane must be balanced in such a manner that the sole is at right angles to the face. This is accomplished by holding it more over to that side of the material which is highest, and supporting it by means

Fig. 174

Fig. 175

of the fingers which are on the face of the material. A series of shavings is then removed until the angle is true, each successive shaving being wider than the former and thicker on that edge which was removed from the high part of the material; this is shown in diagrammatic form in fig. 175.

This is a delicate operation, requiring skilful wrist manipulation, and for this reason forms a valuable manual exercise.

REDUCING TO WIDTH.—The next operation consists of gauging the material to width, which process is explained in Chapter II, "Gauges and Gauging". The material outside the gauge mark is then removed in the manner described for "edge planing". The use of a straightedge is not necessary by reason of the gauge mark being parallel to a straight edge. The try square should, however, be frequently used to test the angle between the face side and back edge.

REDUCING TO THICKNESS.—Both edges of the material are gauged to the required thickness and the material outside the marks removed after the manner described for surface planing.

Common Errors of Beginners.—1. Beginners have a tendency to stand with their feet together at the side of the work rather than behind it, as described.

Fig. 176

2. There is a tendency to apply pressure with the right hand at starting and to apply pressure with the left hand when finishing the stroke, with consequent rounding of surface and thinning of ends (fig. 176).

3. When squaring the edge, the try square is used indifferently from either face of the material instead of "always from the face side". Further, the stock of the square is often not held firmly to the face side and perpendicular to the edge, as it should be.

4. Scholars often gauge their material from the back of the work, i.e. from the untrued surface, instead of always from the face side or face edge.

5. There is a great tendency to go below the various gauge marks. This arises from the fact that scholars, anxious to produce a flat surface or a true right angle, forget, until too late, that there is a gauge mark to be worked to.

These errors are remedied by careful demonstration and patient teaching. Remember that planing is a difficult operation demanding careful thought and action, and whilst perfection is desirable it can only be reached by careful and prolonged training.

Encourage the weak boys and be always alert to detect and correct errors of manipulation. All work should be carried out by easy stages at the beginning.

The Shooting Board and its Use.—Owing to the difficulty of keeping the plane steady when planing the edges or ends of very thin material—i.e. shooting the edges of ends—a shooting board is often used. The shooting board consists of three parts.

A. The surface upon which the work rests.

B. The "stop", which consists of a piece of hard wood dovetailed into piece A, and having the front edge at right angles to the long edge.

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C. A bed on which the plane rests on its side with the cutting edge vertical (fig. 177). It will be seen that the surface A and the face of the plane are mutually perpendicular, hence the squareness of the edge of the material is ensured.

Fig. 177

CONSTRUCTION OF SHOOTING BOARD.—The size varies according to the work to be executed. Serviceable dimensions for manual-training purposes are as follows: Length 2 ft. 6in. Top bed for material (A) out of $4\frac{1}{2}$ in. by $1\frac{1}{2}$ in. Bed for plane (C) out of 3 in. by 1 in. Rails out of 3 in. by 1 in.

Fig. 178

When making shooting boards it is essential that all material shall be planed true. The bearers are recessed, as shown in figure, and the various parts firmly screwed together. A small opening about $\frac{1}{4}$ in. wide separates the "plane bed" from the edge of the "material bed", to allow any shaving to pass through. The "stop" B is made of hard wood and keyed into the top bed, the inner edge making a right angle with the edge

of the "material bed". These details will readily be understood by reference to fig. 177.

METHOD OF USING THE SHOOTING BOARD.—The work is held in position with the left hand whilst the plane is manipulated by the right as shown in fig. 178.

Fig. 179

There is a tendency among beginners to pull the plane over towards them instead of holding it firmly down upon the bed.

Care must be taken when shooting end grain to avoid splitting the work, which can be prevented by first chiselling the corner as indicated in fig. 179. The arrow indicates the direction for planing.

Chamfering.—*In direction of the grain.*—This is usually performed with the jack plane, or with the smoothing plane if the chamfer be small.

The plane is held in the manner indicated for edge planing, care being taken to ensure that the face of the plane is parallel to an imaginary plane passing through the gauge marks.

Fig. 180

Using the Smoothing Plane.—The smoothing plane has many uses, chief of which is that of finally cleaning off a piece of work. Surfaces which are inaccessible after the work is together are first cleaned off before the parts are put together. The exposed surfaces are cleaned off after the work is framed and fixed.

(*a*) *Plain Surfaces.*—The treatment of large plain surfaces needs no special comment. The plane is held in the manner indicated in fig. 163. Needless to say, the plane should be kept exceedingly sharp; the cutting edge should be practically straight but for very slight rounding at the extreme corners, and the setting should be fine.

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(*b*) *Crossing Grain.*—In work where the grain of the various parts is disposed at right angles it will be necessary to hold the plane with its axis oblique to the line of the fibres. By so doing the cutting edge crosses the joint diagonally instead of being presented full width to the cross grain. This prevents the surface being torn up, as would be the case were the cutting to take place at right angles to the fibres of the surface. Fig. 180 shows this in diagrammatic form, the plane being advanced in the direction indicated by the arrows.

Fig. 181

THE SMOOTHING PLANE USED FOR END-GRAIN PLANING.—When cleaning off end grain, the plane should be operated from both ends of the surface to be planed, in order to prevent splitting. This is shown in diagrammatic form in fig. 181; and it will be seen that here also the cutting edge occupies an oblique position.

END-GRAIN CHAMFERING.—This is best performed by the aid of a smoothing plane. The face of the plane should be parallel to the imaginary plane which passes through the gauge marks, but the axis of the plane should be inclined to the direction of the chamfer, thus producing shearing action, which has the advantage of producing clean smooth surfaces and of avoiding splitting at the end of the chamfer. The plane, instead of moving directly forward in line with its axis, is moved bodily forward in the direction of the chamfer (fig. 182).

Fig. 182

Using the Rebate Plane.—Rebates or rabbets consist of rectangular recesses along the edge of the material and can be formed in various ways.

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The dimensions of the rebate are first gauged on each face of the work and either of the following methods adopted according to circumstances.

(*a*) *Using a Fence.*—This consists of nailing a strip of wood to the work having one of its edges coincident with the gauge mark. The plane is worked in the rebate so formed until the gauge mark is reached (fig. 183).

Fig. 183

(*b*) *Using Chisel and Rebate Plane.*—The use of nails to fix the fillet or strip of wood in the previous example damages the surface, and in order to avoid this the following method may be adopted. The dimensions of the rebate are gauged, using a cutting gauge for the purpose. The next step is to chisel out the greater portion of the waste, as indicated in fig. 184, the face of the chisel being uppermost, as described in the chapter on "Chiselling Processes" (see p. 213). When the greater portion of the waste has been thus removed the faces of the rebate are finished by means of the "rebate plane".

Fig. 184

Fig. 185

(*c*) *Forming Grooves.*—When the rebates are large, it is advisable to first make one or more grooves throughout the entire length of the rebate by

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means of a "plough" (fig. 185). The core is then easily removed by chiselling, as in the last example, and the faces finished with the rebate plane.

NOTE.—The plough is a very difficult tool for beginners to manipulate and its use should be restricted to senior scholars. The previous processes afford valuable manual-training exercises, and this is the main point to be kept in view.

Fig. 186

(d) *Rebating by Aid of Side Fillister.*—The side fillister is practically a rebate plane provided with a fence for adjusting the width of the rebate and a "depth stop" which can be adjusted by means of a thumbscrew for regulating the depth (fig. 186). Like the plough, this tool is cumbersome and difficult for beginners to manipulate, and if used in the manual-training room should be reserved for use by senior scholars.

Fig. 187

(e) *Rebating with Sash Fillister.*—The sash fillister is a combination of rebate plane and plough. It is specially constructed for the formation of rebates on the "off side" of the material. It is provided with movable fence and depth stop for regulating the width and depth of the rebate. There is also a side cutter which cuts the side of the groove in advance of the cutting iron, thus yielding a clean surface to the side of the rebate. It is held and manipulated in the manner described for ploughing.

The object of the sash fillister is to enable the planing to take place in

the direction of the fibres and to ensure the rebate being parallel to the face of the material. The principle involved was explained when treating of the planing of sides and arrangement of face marks.

Fig. 188

Use of Plough.—When making grooves running in the direction of the grain it becomes necessary to use a plough. The plough consists of a number of parts, see fig. 187: The stock; cutting iron; wedge; the skate iron; depth stop; fence; beams; wedges for fixing beams in position, thus adjusting position of fence; setscrew for fixing depth stop.

The cutting irons are specially constructed and vary in size according to the width of the groove which it is desired to make. They are prepared in sets ranging from $\frac{1}{8}$ to $\frac{3}{4}$ in. by sixteenths. On the back surface of the iron there is a V-shaped groove extending for a portion of the length and occupying a central position. This groove fits a V-shaped edge on the back portion of the skate iron, thus keeping the iron in a central position and preventing lateral movement.

Fig. 189

The skate iron is about $\frac{3}{32}$ in. in thickness, its narrow edge serving as the "sole" of the plane. To prevent the front end of the skate iron from digging into the material it is rounded, sometimes having a fancy finish, as in fig. 188, thus enabling it to glide over the surface of the material. When setting the plough, care must be taken to ensure that the inside face of the fence is parallel to the skate iron. When sharpening the cutting irons their edges must be kept perfectly square

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in order to ensure the bottom of the groove being parallel to the face of the work.

Having set the plough ready for use it is held in the manner shown in fig. 189. The ploughing should be commenced from the front end of the material and worked down practically to the full depth of the groove, gradually working backwards until the back end of the groove is reached. This is illustrated diagrammatically in fig. 190. The last few strokes should be taken in keeping with the full length of the material.

Fig. 190

Using the Spokeshave.—When curved surfaces are to be planed it is obvious that the ordinary form of plane, with its long and broad flat sole, is unsuited for the purpose. A form of plane having its stock suitably constructed for such work must therefore be used. The simplest form is that of the spokeshave described in the chapter on planes (p. 181).

(*a*) *Convex Curves.*—For these "iron" spokeshaves are most suitable.

(*b*) *Concave Curves.* — When the curves are of small radius, i.e. "quick", small boxwood round-faced spokeshaves are best.

Owing to the small amount of "sole" in contact with the work, the surface of the stock is exposed to a great amount of wear. It is therefore important that, when sawing such curves prior to planing, the surfaces should be kept as even as possible, and only a very small margin of waste allowed.

Fig. 191

The method of holding the spokeshave will readily be understood by reference to fig. 191. The tips of the first fingers should be extended on to the top corners of the stock in order to prevent the tool twisting when in use.

CHAPTER V

Notes of a Lesson on the Firmer Chisel and Comparison with Other Kinds

[NOTE.—Whilst this comparison has been given in the form of "Notes of a Lesson" with a blackboard summary, it is necessary to point out that there is far too much detail for any *one* lesson. It is considered advisable, however, to deal fully with the subject in the form of one lesson, leaving teachers to select just as much of it as will suit the purpose of any lesson they are giving.]

Required for the Lesson.—*Various kinds of chisels* as: Paring, firmer, mortise, register, gouges (scribing and carving).

Specimens of wood: White pine, beech, ash, box, ebony.

Specimens of metal: Cast iron, wrought iron, steel, brass, copper, zinc.

Introduction.—[Exhibit the chisels laid out for the lesson.] What are these instruments called? With which are you most familiar? What is its special name? In this lesson we will deal with this particular chisel. [As the lesson proceeds make comparisons with the other forms which scholars will use later, and on which there must be separate lessons.]

Parts.—HANDLE.—[Refer to handle.] What is this part called? Of what material is it made? Would any kind of wood suit? How did you drive the chisel forward when paring grooves? Are they always pressed forward by the hand alone? How are they sometimes driven? [Exhibit piece of pine.] You have already discovered the character of this kind of wood. Would it answer for chisel handles? What would be likely to happen to it if struck with a mallet? What then must be the character of the wood used for handles? "Hard, tough, strong." Name any such woods. [Explain ash, beech, boxwood. Exhibit specimens. Compare handles with specimens.] Of what wood is this handle made? [Compare comparative cost of different woods. *Boxwood* the best, but costly; *ash* and *beech* suitable and plentiful, hence cheap; *ebony* suitable only for "hand pressure", very costly, very brittle and apt to split if driven with a mallet.]

Top of Handle.—[Allow scholars to compare different kinds.] What do you notice? Why are some flattened, others spherical? Which are spherical? How are these driven forward? Which are flattened? How are they driven forward? One has an iron ring round the top. Why is that? What is the advantage of the rounded end? [Demonstrate: Spherical end fits palm of hand; flattened ends would make the hands sore.]

Shape of Handle.—Are all the handles alike in shape? How do they differ in shape? "Cylindrical—Elliptical" "Curved—Plain". [Refer to each in turn.] How are these handles gripped when in use?

[Exhibit firmer.] Why is this cylindrical? Why so small? Why curved at lower end? [Demonstrate that the curve is made to fit and accommodate the thumb.] [Exhibit "register".] Curve affords a comfortable grip when driving. [Exhibit "mortise".] Not so comfortable to grip, but elliptical section enables the chisels to be kept from turning when in use.

THE FERRULE.—[Refer to Ferrule.] What is this? Why is it necessary to have a band of metal? What is likely to cause the handle to split? What is the "thing" inside the handle for? [Take a chisel to pieces and exhibit the tang.] What happens to the wood when a spike of this character is driven into the end grain? [Demonstrate by driving a large nail into a piece of end-grain wood of small section.] Why is this handle not split? How has the spike been able to accommodate itself without splitting the wood or even spreading it out? [It will be necessary here to explain that when the tang is driven in the fibres of the wood are driven closer together—"compressed".] The fibres tend to escape this compression in an effort to return to their original position. In doing so they press on the "spike", i.e. "tang", setting up sufficient "friction" to hold the spike firmly in the wood. The fibres also tend to escape in an outward direction, but are prevented from doing so by the "band of metal". The pressure of the fibres on the metal tends to pull the metal asunder. Such a pulling force sets up "tension" in the metal. [Explain tension. Mention other examples. The rope in a tug of war, &c.] Of what kind of metal is the band made? [Exhibit specimens of copper and zinc.] Can you name these metals? Each is a piece of pure metal, not a mixture. You will be surprised to learn that when these two metals are melted and mixed they yield a metal such as this band is made of. [Explain when metals are mixed they form "alloys". "Brass is an alloy." Explain: The band of metal we have been discussing is called a "ferrule".]

One chisel has no ferrule; which is it? This has no ferrule probably owing to the large section at the end and the awkwardness of its shape.

One has a ferrule at the top. Which is it? Why has it a ferrule there?

The register pattern has a ferrule at the top, whilst the ordinary mortise chisel has no such ferrule. Why is this? [Explain and compare the difference in sectional area.] Mallet only used on mortise chisel, hammer often used on "register". [Explain: Compression of fibres, due to blow from striking tool. Nature of steel hammer as compared with "wooden mallet" and consequent effect of "time of impact".

(a) *Steel Hammer.*—Hard and unyielding—force of blow localized—time of impact short—reduced time of impact causes reduced effect in blow—localized force and reduced impact lead to sudden shock on material treated, if of wood it causes sudden compression and great tendency to split.

(b) *Wooden Mallet.*—Softer and more yielding—force of blow distributed—time of impact much greater—blow more effective—shock reduced—less tendency to split material—wood too soft, hence only suitable for use on wooden articles.

Note.—Where a driving agent is used to drive forward any object against resistance in the direction of its motion it is necessary that that driving agent should be of harder material than that of the body driven, otherwise the effect of impact will be to damage, "or do work" upon, the driving agent.]

THE BLADE.—[Exhibit a blade.]

THE TANG.—You call this part a spike; its real name is "tang". For what is the tang used? What is its shape? [Lead up to wedge shape in both directions, i.e. "a pyramid".] How does it grip the wood? [Explain: Many tools similarly constructed, a spike-like formation being used to attach the metal portion of the tool to the wooden handle; in all cases this is known as the "tang".]

THE SHOULDER.—[Refer to enlargement at base of tang.] What purpose does it serve? How is the force of the blow transmitted from the handle to the blade? What would happen if there were no "bearing surface". [Explain: The enlarged surface at base of tang is known as the *shoulder*. It serves to receive and transmit the force of the driving blow. It is advisable to call attention to the extra compression set up in the fibres of the wood inside the ferrule, and the consequently increased tension on the metal thereby induced.

Compare area of shoulders.—*Firmer chisels.*—Small—force applied small. *Mortise chisels.*—Very large—have to transmit much greater force. *Register pattern.*—No shoulder. Yet these also have to transmit considerable force. How is this difficulty overcome?

Refer to tang and call attention to large sectional area at base.] When a heavy blow is delivered on the handle the force is transmitted to the blade by the surfaces of the handle in contact with the tang. The "reaction" of the tang tends to split the handle. An enormous amount of compression is set up in the wood, which has to be resisted by the ferrule. Hence the ferrule must be exceedingly strong. [Examine the ferrule.] Of what is it made? Is there any difference in thickness compared with the other ferrules? [It will be necessary to explain that iron resists a much greater tensile strain than brass. Hence the difficulty of having no shoulder is met by using a much stronger material and making the ferrules much thicker.]

THE NECK.—[Call attention to narrowing at top of firmer chisel and gouges, and the absence of such narrowing in mortise chisels.

Demonstrate use of mortise chisel used as a lever to remove the "core" of a mortise.] What would happen if such chisels were narrowed in at the top? Are Firmer chisels used in the manner just demonstrated? [Compare the "register" pattern with others and show that it is much stronger. Explain: In order to reduce the wide blade in a suitable manner to form the shoulder and fit the smaller handle, they are reduced in section as shown, this part being called the neck.] Where are firmer chisels most likely to break? What is most likely to cause them to fracture at this part? "Improper leverage."

THE BLADE PROPER.—[Compare the different blades. (*a*) Some thick, others thin. (*b*) Some wide, others narrow. (*c*) Some flat, others curved. (*d*) Some straight, others bent.

Which chisels are thick and which thin? Explain name of each if not previously mentioned during the lesson.]

Why is this one (mortise) so thick? Why is this one (paring) so thin? [Again compare the work to be executed by each and lead the scholars to see the advantage of each special form.]

FLAT AND CURVED.—[Compare flat chisels with gouges. Explain: Chisels having a flat surface must be used when it is necessary to produce flat surfaces. Gouges used for producing curved surfaces. Curves vary according to particular kind of gouge. Call attention to work executed by each, as: Fluting with firmer gouge; concave curves pared with scribing gouge; carving gouges used for both fluting and rounding.]

STRAIGHT AND BENT.—[Compare ordinary gouges with carving gouges. Explain:

The curves which a carver has to make are often so varied that in order to obtain the necessary "sweep" the blade of the gouge must be bent. *Example.*—Flutes on sharp concave surfaces, &c.]

WIDE AND NARROW.—[Call attention to width as compared with thickness. Explain that width means length of cutting edge in flat chisels, and distance from edge to edge in curved chisels. Refer to mortise chisels, often thicker than they are wide.]

THE GRINDING BEVEL.—[Call attention to grinding bevel on each. How is it produced? Why is it "ground" and not prepared on the oilstone? (See notes on "Grinding"; also "Cutting Action" dealt with later). Call attention to fact that the angle which the grinding bevel makes with the face is much the same in each case. The paring chisel is more acute than the mortise chisel.

Call attention to grinding of gouges. (*a*) Firmer gouges are ground on the convex surface. (*b*) Scribing gouges are ground on the concave side.

Grinding bevel usually inclined at 25° to face.]

THE SHARPENING BEVEL.—[Refer to surface produced by oilstone.] How is this produced? Why is it so smooth compared with the surface produced by the grindstone? Is it necessary to have the surface so smooth? [Explain necessity for having two perfectly smooth plane surfaces intersecting if a keen cutting edge is to be produced.]

Demonstration.—[Take a wedge-shaped piece of wood, and with a gouge make flutes down the face to represent the scratches made by the coarse particles of grit composing the grindstone. Call attention to effect of such grooves (flutes) upon the cutting edge, i.e. its saw-like appearance. What kind of oilstone will produce the keenest cutting edge? Oilstones which produce the keenest cutting edge are usually very slow cutting. For ordinary work one of "medium cut" is used. (See note on "Oilstones").]

THE CUTTING EDGE.—[Allow scholars to examine with a lens and notice the serrated appearance of edge.] How can this be reduced to the minimum?

THE FACE.—[Call attention to smooth character of face in all cases.]

COMPOSITION OF BLADE.—[Refer to stamp on chisel "cast steel". Of what is the blade made? Explain: Though made of cast steel it does not mean that the blades are cast in moulds to their particular shape.] Cast steel refers to a particular variety of steel used for the manufacture of chisels. Bars of cast steel are forged to the shape required. The chisels are then ground, hardened, and tempered.

[Compare wrought iron—steel—cast iron. Refer to similarity in appearance. Demonstrate ease with which cast iron can be broken. Call attention to *brittle* character. Fracture a piece of wrought iron. Call attention to repeated bending required. Note fibrous character of fractures. Exhibit specimen of fractured steel, if available, and compare fractures in all cases. Explain: Brittleness in iron induced by a substance called "carbon".] Which specimen contains most carbon? Which contains least carbon? Iron containing no carbon is known as wrought iron, and is *ductile and flexible*.

NOTE.—*Ductile* = capable of being drawn out. *Flexible* = capable of being bent.

When iron contains a small quantity of carbon up to about 2 per cent it is known as steel. The carbon makes it exceedingly hard and "elastic", and also enables it to be "tempered".

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The harder varieties of steel are forged only with difficulty, steel must on no account be heated to the same degree as wrought iron when being forged.

Steel is the only metal capable of being "hardened" *and* "tempered", other metals can be "hardened" but not "tempered".

When iron contains more than 2 per cent of carbon it is known as "cast iron". It cannot be forged on account of its brittle character. It is melted and moulded to shape.

USE OF CHISELS.—For what are all kinds of chisels used? The action of most chisels in removing a thin shaving is known as "paring".

NOTE.—*Paring* = the act of reducing by removing thin shavings.

BLACKBOARD NOTES

A FIRMER CHISEL

B. B. Sketch

Definition.—An instrument used for paring wood.

Parts.—A. *Handle.*—Wood—boxwood, beech, or ash.

Shape.—Top portion, cylindrical; lower portion, shaped to fit thumb.

B. *Ferrule.*—Brass—prevents handle splitting.

C. *Tang.*—Position: Portion inside handle. Use: Fixes blade to handle. Shape: In form of a pyramid.

D. *Shoulder.*—Expanded portion of blade at base of handle—Prevents blade driving too far into handle.

E. *Blade.*—Cast steel—Forged and ground—Contains small quantity of carbon—Can be tempered.

F. *Neck.*—Blade narrowed in to fit shoulder.

G. *Face of Blade.*—Flat side—Copying surface.

H. *Grinding Bevel.*—Produced by grinding; angle between bevel and face 25°.

I. *Sharpening Bevel.*—Produced on oilstone; angle of 35° with face.

Size of Chisel.—Width of blade.

Kinds of Chisels.—(A) Paring; (B) firmer; (C) mortise; (D) gouge; (E) register.

B. B. Sketch

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CHAPTER VI

Chiselling Processes

It will be found that the exercises of Part III afford facilities for using the chisel in many and various ways. The operations involved have, as far as possible, been arranged in order of difficulty. In this chapter it is proposed to deal with each as a separate tool exercise. The articles quoted in parentheses as examples of the various operations are selected from Part III, in which full particulars of their construction, with illustrations, will be found.

The Firmer Chisel.—HORIZONTAL PARING AT RIGHT ANGLES TO THE FIBRES.—An example of this type of paring is afforded in the first series of grooves. The sides of the grooves must first be sawn, care being taken to ensure that the "kerfs" made by the saw form part of the groove.

Fig 192

Having sawn the grooves the work should be fixed in the vice as indicated in fig. 192. The chisel is grasped easily but firmly in the right hand with the handle bedded comfortably in the palm. The thumb should be on the top of the handle whilst the first finger points in the direction of the blade, the remaining fingers being clasped round the handle.

The left hand should be placed over the blade as shown in figure.

The left elbow should rest on the work, as indicated. In order that this position may be comfortably occupied it will be found necessary to extend the right leg backward, both knees being slightly bent.

The chisel should have the face side, i.e. "flat side", downwards. The chisel is driven forward with the right hand, and its motion controlled and

regulated by means of the left hand, which acts as a repressing agent working about the left elbow as a pivot.

For ordinary grooves the chisel should be pushed about halfway across the material and the process repeated until the gauge mark is reached, when the material should be reversed in the vice and the chiselling repeated until the gauge mark on that side is reached. The bottom of the groove should then be tested for flatness by the aid of the try square, and any errors corrected.

The shaving should at all times be thin, in order to ensure true cutting as distinct from the splitting action of the "wedge-shaped" chisel.

All strokes should be steady and continuous—not jerky. Jerky chiselling leads to splitting and the production of uneven surfaces, owing to the lack of control.

ERRORS COMMON TO THIS FORM OF CHISELLING.—It is often found that all the fibres of the material composing the waste to be removed have not been sawn through, i.e. the teeth of the saw have not reached the gauge marks on the opposite surfaces simultaneously. When chiselling, the fibres which are not sawn through are lifted by the chisel and burst or splinter in the centre, but remain attached to the sides of the grooves. How are these to be removed? In the first place the sawing should be carefully watched and scholars made to test it by placing the saw in the kerf and examining whether the teeth touch both gauge marks at the same time. Any uncut fibres in the centre of the material will prevent the saw reaching the gauge marks. This should be corrected by further use of the saw.

In the endeavour to avoid going below the gauge marks with the saw it is often found that there still remain a few uncut fibres, and it is not advisable to return to the use of the saw to sever them. Two methods are available for severing these.

Fig. 193

SHEARING CUTS.—(*a*) By holding the chisel firmly on to the bottom of the groove and pressing its edge firmly against the side of the groove. If the chisel be now steadily advanced, the edge *a* of the sharpening bevel, fig. 193, appears to rise up the side of the groove and the fine fibres which protrude are shorn off. This affords an opportunity of calling attention to the "shearing cut" as distinct from cuts made with keen cutting edges. Refer to action of scissors and shearing machines.

(*b*) The chisel is held in a slightly inclined position, as shown in fig. 194.

with its face firm against the side of the groove. It is then drawn towards the operator in the direction indicated by the arrow, thus severing the fibres, which can afterwards be removed by chiselling in the ordinary way.

Fig. 194

Fig. 195

METHOD TO BE AVOIDED.—Left to themselves, scholars are very apt to adopt the method indicated in fig. 195, with the result that the side of the groove is chiselled and faulty. This method should on no account be adopted.

HORIZONTAL PARING OBLIQUE TO THE FIBRES.—This application of the chisel is involved in the series of grooves forming the second portion of the first exercise.

The wood should be fixed in the vice as in the previous example.

The chisel is held in a similar manner to that already described, but the body is ranged in line with the direction of the groove.

Fig. 196

In this example there is no necessity to chisel from opposite sides. The exercise should be turned in such a manner that, when chiselling, the cuts are made in the direction in which the fibres are running. The chisel should be kept in a horizontal position and pushed steadily across the full width of the material. What has already been said concerning uncut fibres and the method of removing them can be applied in this case.

VERTICAL CHISELLING OR PARING.—This method of chiselling is often adopted for removing corners, paring the end of material, and forming convex surfaces which cannot be finished with the spokeshave.

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Flat Cuts.—The chisel should be held in the manner indicated in fig. 196. The handle is firmly clasped in the right hand with the thumb on the top. The blade is held and guided by means of the thumb and first finger of the left hand, the lower portion of the hand also serves to keep the material in position on the "cutting board".

When wide cuts have to be made, care must be taken to study the nature of the material to be cut and advantage taken of the "wedge action"

Fig. 197

Fig. 198

of the chisel. Fig. 197 illustrates the correct method of chiselling a wide surface, and fig. 198 an incorrect method with consequent splitting.

SHEARING CUTS AND CHAMFERING.—(*a*) *Cross grain—at right angles.* (*Example.* EXERCISE IV, p. 251. Keyboard.)—When small chamfers have to be formed on the cross grain, they are usually made with the chisel. For this purpose the material should be fixed in the vice in an inclined position, as indicated in the figure. The chisel is held in a manner similar to that described for grooving. The cutting edge of the chisel occupies an oblique position relative to the fibres, which position is maintained during the removal of the shaving. The chisel is not pushed forward in the direction in which it is pointing, but is drawn obliquely across the material as indicated by the arrow in fig. 199. This action shears off the material and has the effect of producing a smooth surface and avoids the tendency to split which arises when the chisel is held at right angles to the material and pushed forward in line with the axis of the chisel.

(*b*) *Cross Grain—Oblique.*—In this case it is not necessary to adopt the shearing principle, but the chisel may be held in line with the chamfer to

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Fig. 199

be formed and pushed directly forward, care being taken to ensure that the cutting takes place in the direction of the fibres (fig. 200).

(c) *In Direction of Grain.* (*Example.* — Oxford picture frame.) — It often happens that chamfers have to be formed which run in the direction of the grain. If these be continuous throughout the length of the material a plane should be used, but in cases where they do not extend for the full length of the material the chisel must be used. The chisel should be applied in the manner described above in Section *a*, and very thin shavings should be taken.

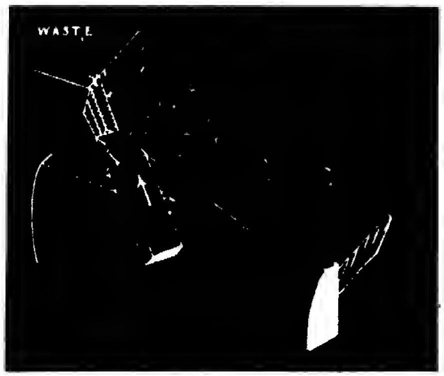

Fig. 200

It is important to see that the face of the chisel is held at the proper inclination in order to allow the chisel to be carried the full length of the

chamfer without altering the inclination. The cuts must be made in the direction of the fibres (fig. 201).

Fig. 201

Fig. 202

(d) *Curved Chamfers.* (*Examples.*—Bread board; photograph frame.)—When the curves are sharp it is often impossible to use a spokeshave for such chamfers; the difficulty in such cases is overcome by using a chisel with the bevelled side towards the material. The principles involved and cutting action employed are as already explained. It will readily be understood that this type of chiselling requires skilful wrist manipulation. Fig. 202 illustrates the process.

Fig. 203

This method is also applied to the formation of "curved stops" to stop chamfers.

Paring Obliquely in the Direction of the Fibres.—(a) *Continuous cuts.* (*Examples.*—Key label; bearer for egg stand; pin for lapped dovetail.)—This is a fairly simple operation. It is necessary to maintain perfect control

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over the action of the chisel by means of the left hand. Fig. 203 indicates in a general way the method of manipulating the chisel.

The work is so arranged that the direction of the cut becomes as nearly as possible horizontal.

(*b*) *Stopped Cutting.*—When forming

Fig. 204

Fig. 205

the dovetail pin the left hand must exercise a repressing action in order to prevent the fitting shoulder being damaged by the chisel (fig. 204).

(*c*) *Oblique Notching.* (*Example.*—Bearers for the egg stand.)—Having marked out the material, a saw kerf is made as shown in fig. 205. It is advisable that the kerf should not extend quite to the line. The chiselling should be proceeded with by working alternately from opposite sides until the last cuts intersect at the bottom of the notch. Should one side be entirely finished before starting the other, it will readily be seen that there is a danger, when chiselling the second portion, of the chisel slipping and damaging the finished surface.

The chisel must be carefully repressed as it nears the intersection at the base of the notch.

Fig. 206

VERTICAL PARING OF CURVED SURFACES. —(*a*) *When the curve is free throughout its length.* (*Example.*—Luggage label.)—The chisel should be held as already described. Fig. 206 should make clear the effect of the chisel. The action of the wedge-shaped chisel will be to split the wood. Should the chiselling be commenced as at *a* the chisel will force

the waste out in the direction indicated by the arrowhead, and as the fibres of the wood are continuous past the corner of the chisel, splitting will take place as shown. The chiselling should therefore be commenced as shown at *b*, fig. 206; splitting still occurs along the dotted line shown, but the waste is free to move forward in the direction indicated by the arrow without the split running into the inner portion of the model.

(*b*) *Confined Curves.*—An example of this type will be found in the small curve on the support of the wall bracket.

Saw kerfs should be made at *a* and *b*, as in fig. 207, and the chiselling can then be proceeded with as in the last example. A small chisel should be used for this exercise. To finish the "flats", fix the wood in the

Fig. 207

Fig. 208

vice and vertically chisel the end at *a*, surface *b* being pared horizontally and vertically.

STOPPED GROOVING. (*Example.*—The wall bracket.)—Having set out the groove, the stopped end must be mortised as shown at *a* (fig. 208). The tip of the tenon saw can then be worked in these mortises, and the groove sawn in the usual way.

MORTISING.—(*a*) *Open Mortises.* (*Examples.*—Mortise in bridle joint, footstool, slots for dovetails.)—The work having been set out, the sides of the openings are first sawn. The bulk of the waste may then be removed in one of three ways:—

(1) By boring a hole as shown at (*a*) (fig. 209), the waste piece may easily be knocked out.

(2) By mortising as indicated at (*b*) in fig. 209. This method, though often adopted, entails loss of time and waste of energy.

(3) Where large slots have to be made, the sides are first cut with a tenon saw. A bow saw is then run into the cuts, and turned to cut across the grain at $a\,b$ (fig. 209), thus liberating the waste. Care must be taken to avoid running the saw into the sides of the slot. Having sawn out the waste, the fitting surfaces are finished by paring back to the line with a thin sharp chisel.

(*b*) *Through Mortising.* (*Examples.*—Mortise-and-tenon joint, towel

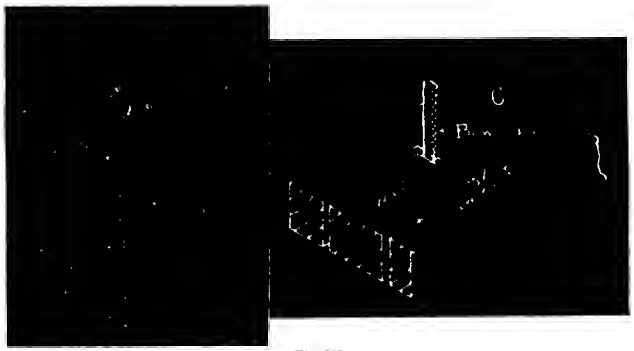

Fig. 209

roller.)—The method of setting the mortise gauge and gauging is dealt with elsewhere.

When the mortise has to pass entirely through the material, care must be taken to start from the back edge. This is very important where allowance has to be made for wedges. Assume $a\,b\,c\,d$ (fig. 210) to represent the mortise. The chisel is held in a vertical position, with the cutting edge a short distance forward from the end of the mortise, as at $e\,f$, when a firm steady blow is delivered on the handle, driving the chisel into the material, and thus forming a shallow wedge-shaped opening. The chisel is now moved slightly forward, and, being held vertically, is again driven into the material. The action of the chisel should now be carefully studied. This is shown diagrammatically in fig. 211. The chisel is wedge-shaped, and when the blow is delivered upon the handle its force is resolved into angular components acting at right angles to the planes of the wedge. (Shown in the figure by the small arrows.) These forces seek release in the line of least resistance, which is clearly in the direction

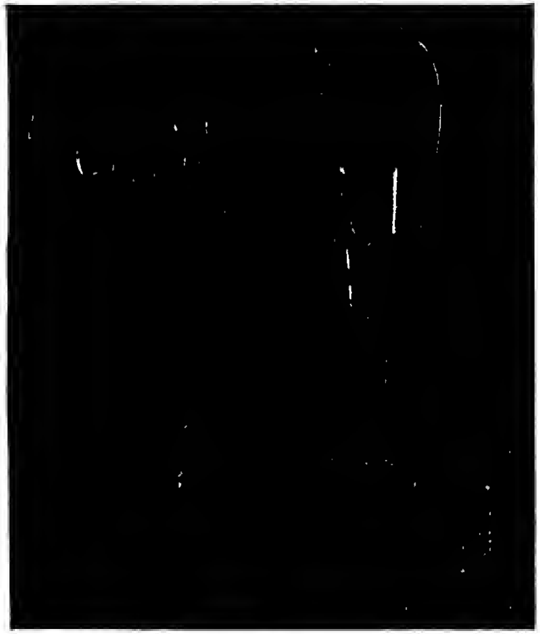

Fig. 210

Fig. 211

Fig. 212

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of the arrow marked *a*, the effect being to overcome the cohesion existing between the fibres, thus forcing the small piece of waste into the opening first formed, when it can easily be removed by using the chisel as a lever, as in fig. 212. Edge *a* acts as a fulcrum, about which the chisel turns. This process is repeated, and at each stage the face of the chisel is brought slightly nearer the end *a b* of the mortise. When the mortising has been carried near to the end *c d* (fig. 210), the chisel must be turned round so that the face of the blade is presented to line *c d* and a vertical cut made. The finished edges of the mortises must on no account be used as fulcrums, otherwise the material will become bruised, and bad fitting will result.

Fig. 213

Having driven the mortise slightly more than halfway through the material from the back edge, the material must next be turned over and the process repeated, the cuts meeting in the centre of the material. Care should be taken to see that the work does not rest on any of the loose core.

It is essential that the chisel be not inclined to either side. The axis of the chisel must be in a plane parallel to the face of the work, as in fig. 213.

Fig. 214

The method of holding the chisel and delivering the blow is shown in fig. 210.

(*c*) *Stopped Mortising.* (*Example.*—Mirror frame.)—It is necessary that mortises be stopped as in this example, where to have the tenon showing would give an unsightly appearance to the work.

The process is similar to that already described. Care must be taken to avoid driving the chisel too far into the material. The depth to which the chisel is to enter the material may be indicated by gluing a strip of paper on either side of the chisel, as shown in fig. 214.

Scribing. (*Example.*—Corners of frame for towel roller.)—This is but a

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repetition of the process described under "Vertical Paring" on page 207, the scribing gouge being used in place of the firmer chisel. Here, too, the tendency of the material to split must be carefully studied and taken advantage of.

PARING LARGE FLAT SURFACES. (*Example.*—Under surface of simple inkstand.)—This exercise requires considerable skill, and the success of the operation depends upon the full realization of the possibilities of the chisel as a "copying tool". It has already been pointed out that the "face" of the chisel blade is a plane surface, which surface can be used as a guiding agent for the production of other plane surfaces in the substance of the wood. Having marked out the waste in the usual manner, make several saw kerfs from $\frac{3}{4}$ to 1 in. apart. The kerfs should be carried to within about $\frac{1}{64}$ in. of the gauge mark. The waste may then be removed, as if treating a series of grooves. To finish the surface, first ascertain in which direction the fibres run, and so arrange the exercise in the vice that this direction runs from left to right. Commencing at the left end, a portion should first be chiselled flat, from gauge mark to gauge mark. This should be carefully tested by means of the try square. This true portion serves as a "rest" for the chisel whilst the flat surface is being extended. The chisel should not be used as in the case of ordinary grooves, but is worked with a scythe-like motion, with as much of the face as possible working on the flat surface first produced, whilst only the right corner of the blade is used for extending the cut, the motion being indicated by the series of arrowheads in fig. 215. The shavings should be exceedingly thin, and it is advisable not to attempt finishing the surface in one cut. It will be seen

Fig. 215

that the action partakes of the nature of a shearing cut, working in the direction of the fibres.

Fluting. (*Examples.*—Simple inkstand, larger inkstand, medicine cabinet.)—The firmer gouge is used for this purpose, and the bevelled side is turned to the work. The shaving must be thin, as, owing to the curved shape of the blade, when force is applied to the handle it is resolved into components acting normal to the curve of the blade, the effect being that considerable compression is set up in the material composing the shaving, thus retarding the forward motion of the gouge.

Rebating with the Chisel. (*Example.*—Oxford picture frame.)—When the rebate is not extended for the full length of the material it is impossible

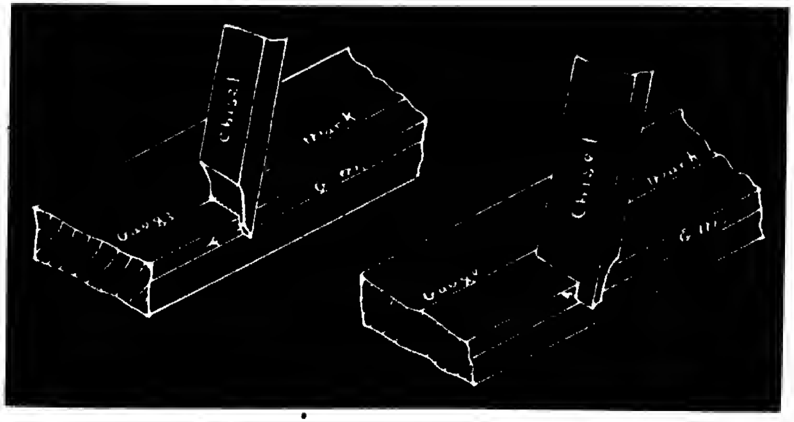

Fig. 216 Fig. 217

to use the rebate plane in the ordinary way. Recourse has therefore to be had to the chisel in order to remove the waste. See fig. 184.

Having gauged the rebate, the chisel is held in the left hand with the bevel side downwards. The exercise affords a useful example of the assistance gained by a correct use of the "inclined plane" principle underlying the construction of the chisel.

If the chisel be held as shown in fig. 216 it will be seen that the surface of the sharpening bevel stands practically at right angles to the fibres of the

wood, and before the chisel can enter it must compress the fibres in the direction indicated by the arrows, such compression entailing the expenditure of a considerable amount of energy which is not utilized to best advantage.

Compare this action with that shown in fig. 217, where it will be seen that the face of the chisel is inclined to the line of the fibres, the action of the face of the chisel, together with the reaction of the wood under the chisel, tending to lift the waste material at each stroke as indicated by the arrows. In this method there is little compression, and the energy is used to best advantage. Having made a series of cuts with the chisel, the waste is easily removed, and the surface may then be finished by paring in the ordinary way.

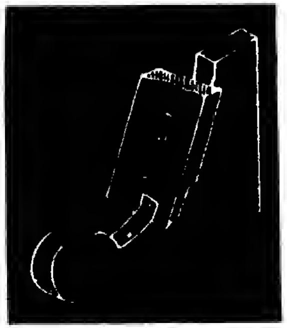

Fig. 218

ROLLING CUTS. (*Example.*—Brackets for shelf on mirror frame.)—The curves are of such a character that it is impossible to finish them with the spokeshave. It is therefore necessary to use the chisel for the purpose. The method of doing so is indicated in fig. 218. The chisel is held with the bevelled side towards the work, and is carefully controlled and made to follow the direction of the curve by means of the wrist.

When the chisel is reversed in this manner the difficulty of manipulating it is much increased, as the surface of support is only equal to the area of the sharpening bevel.

CHAPTER VII

Boring Tools

Bradawls.—CONSTRUCTION.—Bradawls consist of two main parts: (*a*) The blade, (*b*) the handle.

The blade is made from steel wire of the recognized standard gauges. The cutting end is drawn down to a wedge-shaped end, whilst at the top end a "shoulder" and tang are formed. The handles are made of boxwood, ash, or beech: the shape adopted affording a convenient grip when in use.

The blades are very apt to work loose in the handles. This is overcome by means of a rivet which passes through the ferrule, handle, and tang; but of course such a rivet is somewhat inconvenient when it becomes necessary to renew the blade. Other methods of fixing the blade to the handles take the form of specially constructed ferrules.

Cutting Action.—The bradawl is one of the most primitive boring tools. The cutting edge severs the fibres, and by means of the turning motion imparted by the hand the fibres are compressed, but not removed. Whilst this operation presents little difficulty in the case of soft woods, it will readily be seen that there will be a great tendency to splitting when this action is applied to dense hard woods; and particularly is this the case when boring holes near the end of a piece of wood.

Fig. 219

When starting a hole the cutting edge should be placed across the fibres, in order to cut them transversely. If arranged in the other direction, the wedge action of the blade acts at right angles to the fibres, causing the material to split (see fig. 219).

BLACKBOARD NOTES

BRADAWLS

Definition.—Instruments used for boring small holes—Primitive form of boring tool.
Parts.—

Handle.—Box, beech, or ash, shaped to fit hand.
Ferrule.—Brass—Prevents handle splitting.

Blade.—Cast steel—Forged to shape.
(*a*) Cutting edge.—Wedge-shaped form.
(*b*) Shoulder.—Enlargement of blade; prevents blade driving too far into handle.
(*c*) Tang.—Tapering prong for fixing blade to handle.
Rivet.—Prevents blade working loose.

Method of Using.—Cutting edge arranged across fibres at starting.

Gimlets.—This form of boring tool has undergone many changes during the process of evolution. It took its rise from the bradawl, the first change being the substitution of a pod-shaped blade in place of the solid cylinder. The sides of the pod performed a certain amount of cutting, thus reducing the compressile forces set up in the material when large holes were being bored. The use of such instruments demanded the exercise of much muscular energy, and the instrument had constantly to be removed in order to discharge the "core". Later, the screw point was introduced. This served to reduce the amount of muscular energy required to drive the instrument forward, but did not overcome the necessity for its removal to discharge the core. This difficulty was overcome by the introduction of the "spiral twist", which acts as an inclined plane, causing the core to rise and discharge at the surface as the instrument is rotated.

The form of handle adopted is invariably the "tee" shape. This affords a considerable amount of leverage (see Chapter XI).

The auger is merely an enlarged form of gimlet used for boring large and deep holes. The handle is much longer, and the necessary force is applied by using both hands.

Construction.—Gimlets consist of two main parts: (*a*) the blade; (*b*) the handle.

The blade is forged and ground to the required shape; the screw point being cut in a lathe. The top end of the blade is made in the form of a pyramid of quick taper which passes through the handle, and is riveted over a small brass or copper washer.

The handle is simple in design. It is cylindrical in form, with hollows to accommodate the thumb and finger, and is usually made of boxwood or some hard, tough wood to resist the tendency to split when in use. The washer prevents the handle from splitting when the end of the blade is riveted, and also keeps the blade from working loose, as would happen were the riveted end of the blade to act directly on a wooden surface.

BLACKBOARD NOTES

GIMLETS

Definition.—Instruments used for boring holes in wood, ranging from $\frac{1}{8}$ in to $\frac{3}{8}$ in

Kinds.—

A. Shell.
B. Twist } Various forms—act as an inclined plane—removes core
C. Swiss }

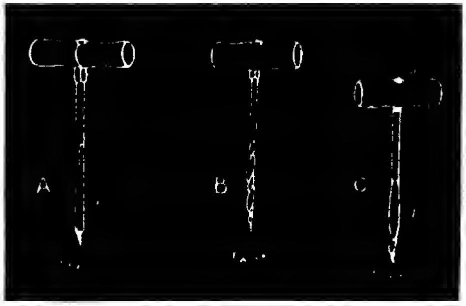

Fig. 220.—B. B Sketch

Parts.—

Handle (boxwood), cylindrical in form.
Blade (steel), forged—ground and turned to shape.
(a) Screw at end draws the instrument into the wood—reduces muscular effort required.
(b) Shell cuts away core—removes waste.
(c) Tang—form of pyramid—fixes handle to blade—end riveted.
(d) Washer (brass or copper) distributes pressure of rivets.

Brace and Bits.—The cutting action of bradawls and gimlets is not continuous. In the case of the gimlet the position of the hand has to be changed at each half-turn. The brace overcomes this difficulty and enables a continuous rotary motion to be imparted to the various cutters, called "bits". The brace has undergone many changes during the process of evolution. The underlying principle in its construction is the application of the "crank", or bent arm. The crank enables continuous motion to be imparted, and affords greater leverage when in use. Space will not permit a detailed account of the evolution, but this has been mainly along the lines

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of reducing the friction in the working parts, and improvements in the method of clasping the bits; the final product being the American pattern ratchet brace, with polished or nickel-plated steel bars, having spring jaws and fitted with anti-friction "ball-bearing" collar.

Fig. 223

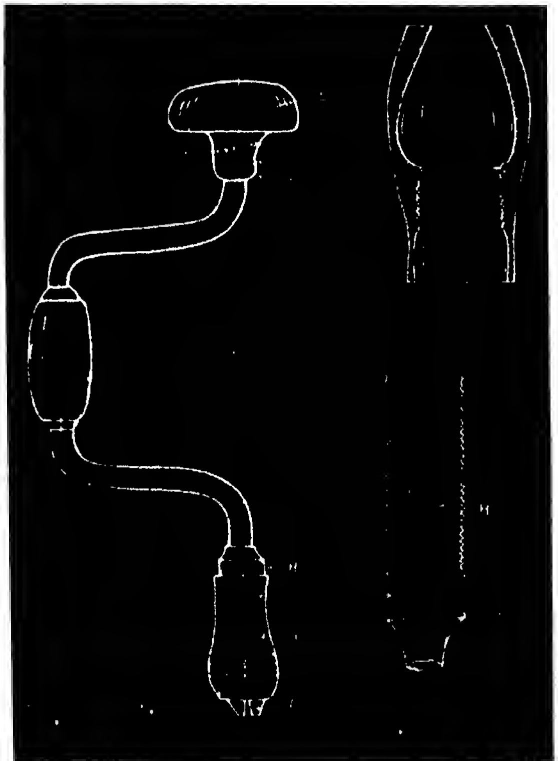

Fig. 221 Fig. 222 Fig. 223, see above

CONSTRUCTION.—The brace consists of three main parts: (1) the head; (2) the crank; (3) the chuck—as will be seen by reference to fig. 221.

(1) *The head* (A) is formed of hard wood, and is shaped to fit the hand. It is attached to a steel sleeve (B) which is flanged and screwed to the wooden head. It fits over the end of the crank rod and has its bearing on hardened steel balls, which in turn work on a hardened-steel collar (C and D) attached to the crank rod and forming an abutment for the head. This will readily be understood by reference to fig. 221. The hardened, steel washer (C) prevents wear, and the steel balls reduce the amount of friction

(2) *The Crank.*—This consists of a rectangular bend in the rod (E), varying in amount from 4 to 5 in. The instrument would be inconvenient to work were these dimensions exceeded, as it would strike the chest at every rotation. The diameter of the circle traversed during one rotation is known as the "sweep", which varies from 8 to 10 in. The size of the brace is known by its sweep. The crank is fitted with a hard-wood handle (sleeve) (G), having brass or steel bushes and working between collars (F) which are forged on the crank, thus preventing the handle (sleeve) sliding up and down the crank. The sleeve is shaped to afford a good grip. Some braces have no handle, in which case all the friction due to rotation of the brace falls on the hand.

(3) *The Chuck.*—It is here that the greatest improvements have been effected. The early forms were provided with a rectangular tapering hole into which the end of the bit was fitted, being kept in position by means of a spring or thumb-screw. The modern chuck is a great improvement upon this, as it enables bits of varying sizes and shapes to be firmly gripped. The end of the crank rod is enlarged to about 1 in. in diameter, and is threaded for the greater part of its length; it is also slotted for the purpose of receiving the "jaws" (H), (enlarged details, fig. 222).

Fig. 224

A socket is fitted to the screwed portion just described, the front portion projecting beyond the crank rod, and having the inside shaped in the form of an enlarged hollow cone (fig. 223). The hollow cone corresponds in its taper to the sloping sides of the "jaws", which fit loosely into the socket formed in the crank rod. Hence, as the socket is screwed on, its inner surface closes the jaws, which in turn grip the bit.

The jaws consist of two pieces of hardened steel loosely riveted at the bottom and made to open by means of a steel wire spring. The top outer surfaces taper to the section of a cone corresponding to the inner side of the socket. The inner faces of the jaws are recessed, the recess being small at the top and large below for the purpose of fitting over the enlarged ends of the bits, thus preventing the bits falling out when in use. The details are shown in fig. 224.

The ratchet is a contrivance for enabling the chuck to be driven in one

direction only. Small levers or pawls are placed on each side of the chuck which, by means of a revolving collar, are made to engage with racking formed on top part of the chuck (fig. 225). The pawls may be so arranged that when the brace is driven clockwise it carries the chuck with it, but when driven anti-clockwise the chuck remains stationary. By altering the rotating collar and reversing the pawl engaged, a reverse action may be obtained, or by allowing both pawls to engage, the chuck may be turned in either direction. This arrangement is very convenient for enabling holes to be bored in confined spaces which do not permit of the free sweep of the brace.

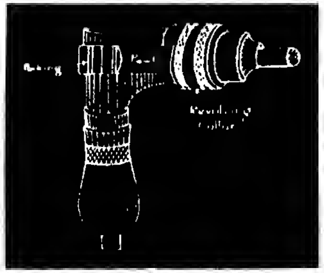

Fig. 225

Fig. 226

METHOD OF HOLDING.—This will readily be understood by reference to the accompanying figure (226).

BLACKBOARD NOTES

THE BRACE

Definition.—A crank-shaped instrument for holding boring tools and affording leverage during the process of boring.

Parts.—

Head.—Hand rest of hard wood, flanged steel sleeve screwed to head, fitting over crank rod.
Ball bearings resting on hardened-steel collar.

Crank.—Crank rod bent to rectangular form 4 to 5 in. long. Sweep, 8 to 10 in.
Affords leverage.
Provided with hard-wood handle (sleeve).
Handle works between collar—ball-jointed.
Handle reduces friction on hand.

Chuck.—(*a*) Enlargement of crank rod—slotted—screwed.
(*b*) *Socket.* Screwed to fit crank rod. Inside of top—enlarged hollow cone, fits over jaws.
(*c*) *Jaws*—two pieces—fit into slot—loosely riveted at base—opened

by steel wire spring—closed by inner surface of socket—Inside faces recessed to fit over end of bit.

Ratchet.—Contrivance for governing motion of chuck.

CHAPTER VIII

Hammers and Mallets

Definition.—Hammers and mallets are instruments used chiefly for delivering blows, the force of the blow acting as a propelling agent on other tools or bodies.

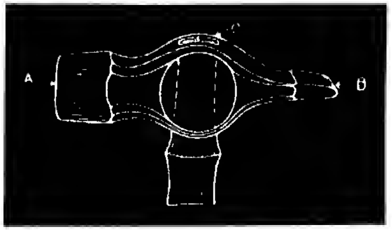

Fig. 227

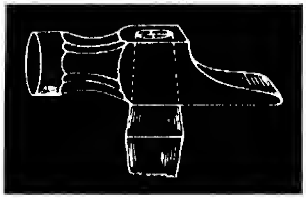

Fig. 228

Varieties.—Many different varieties of hammers are in common use, each having its particular shape and serving its own special use.

The chief patterns are: The joiners' hammer or "Warrington" pattern (fig. 227); the "Exeter" or London pattern (fig. 228); the "Canterbury" claw hammer (fig. 229); the adze-eye or "American" claw (fig. 230).

There is very little variety in the form of mallet adopted for use by woodworkers.

Parts. — Hammers

Fig. 229

Fig. 230

and mallets are divided into two main parts: (*a*) the head; (*b*) the shaft or handle.

THE HEAD.—Hammer heads are made of cast steel, and are forged to the required size and shape. The shape depends upon the particular type of hammer being formed and the "balance desired".

The head is divided into three main parts, as shown in fig. 227: (A) the face; (B) the pane; (C) the eye.

THE FACE.—This is the most important part of the head. It is cylindrical in form, having the striking surface slightly convex, and its diameter varies in keeping with the weight of the head.

THE PANE.—The back end of the head is known as the "pane", and varies in shape according to the particular pattern of hammer. For woodworking purposes they are usually flat, as in the "Warrington" and "Exeter" patterns, or curved, as in the claw hammer.

(*a*) *The cross pane* is wedge-shaped, having its edges at right angles to the axis of the handle. The edge is rounded. It is used for driving nails situated in confined places.

(*b*) *The Claw.*—In this case the pane is in the form of a curved wedge having a triangular split in the middle. The thin end of the wedge enables it to be inserted under the head of any nail that has to be extracted, the head being gripped in the triangular split. The opening in the claw is also triangular in section, thus preventing any tendency of the nail to slip.

THE EYE.—This is the name given to the hole through the head into which the handle or shaft is fitted.

The eye is elliptical in shape, and is smaller towards the middle than at the outsides. Care has to be taken during the process of forging the head to ensure that the hole is centrally placed in keeping with the axis of the head and handle, otherwise the hammer will not "hang" true.

There is no eye in the head of the Canterbury pattern. The head is forged with two flanges which extend along the sides of the handle. The handle is fixed to the head by means of rivets which pass through flanges and handle. It will readily be seen that such an arrangement is not suited for resisting the sudden shocks due to heavy blows, or for resisting the strain due to leverage exerted when extracting nails.

Sizes range from 0 to 10.

THE HANDLE OR SHAFT.—This must be made of wood which is flexible in character. Ash and hickory are most suitable for the purpose. The flexibility of the handle plays a very important part in the effective force of the blow,

serving as it does to lengthen or diminish the time of impact. The handle is elliptical in section, thus affording a good grip when in use, also serving to keep the axis of the head in line with the direction of the line of force of the blow. The end which passes through the eye is conical in shape, and is firmly fixed to the head by means of an iron or wooden wedge driven into a saw cut which is made in the end of the handle before the handle is driven into the eye. The end of the handle which is held in the hand is made of suitable section to afford a comfortable grip; the upper portion near the head is usually reduced in section in order to increase the amount of flexibility. The length varies in keeping with the weight of the head.

Handles should be made of wood that has been thoroughly seasoned, otherwise, when in use they are apt to work loose in the eye.

PROCESS OF MANUFACTURE.—The heads are forged to the desired shape from cast steel, and the faces have to be very carefully hardened and tempered to withstand heavy blows. It is essential that all parts of the face be uniformly tempered. The central portion surrounding the eye must be annealed in order to prevent fracture.

METHOD OF USING HAMMERS.—The effective force of blows delivered depends upon the amount of leverage exerted, together with the momentum of the head.

For light blows the weight of the head falling through a small distance and actuated from the wrist is sufficient.

Heavier blows are obtained by exerting leverage from the elbow or shoulder and causing the hammer to fall through a greater arc.

The handle should be easily but firmly gripped in the right hand, as near as is convenient to the end farthest from the head, as in fig. 231.

Whenever possible the work should be so arranged that the blows from the hammer fall vertically, as in this manner the force of gravity materially aids the operator and the process of hammering is less tiring.

At the time of impact the axis of the hammer head should be normal to the surface struck.

The hammer should not be used for delivering blows on wooden surfaces. Owing to the great density of the steel, and the small area of the face, the force of the blow is concentrated upon a small area, and the suddenness of the shock, due to the unyielding character of the dense steel, produces unsightly bruises in the surface of the work, and may even rupture the fibres.

Experiment.—Deliver a few heavy blows upon the surface of a piece of

wood, producing the bruises described. Plane the surface until it is again flat. Wet the surface and note results.

This experiment is to make clear to a class the detrimental effects of using

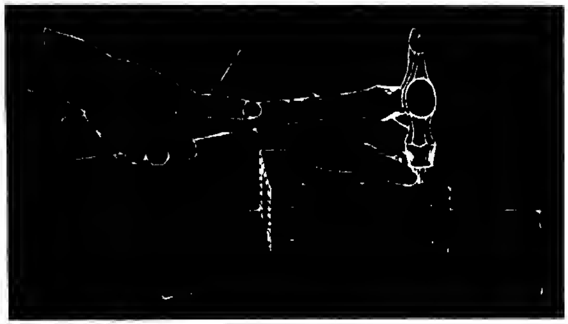

Fig. 231

the hammer upon the surface of their work, particularly where such work is subsequently to be painted, stained, and varnished or polished.

MALLETS.—These are simply forms of wooden hammers. They are usually made of beech, hickory, or *lignum vitæ*.

Fig. 232

The head is usually rectangular in section. The top curve forms an arc of a circle the centre of which is at, or about, the position of the elbow. The faces form "radii" of the circle.

The eye is rectangular in section. The two ends of the eye taper towards the inside of the head, whilst the sides must be parallel (fig. 232). The handle is inserted from the top and maintained in position by the centrifugal force of each blow. The reactions of the wedge-shaped handle act on planes at right angles to the direction of the fibres. Were the handle to taper in both directions it will readily be seen that the effect of the centrifugal force would cause the wedge-shaped handle to split the head. The size is indicated by the length of the head, and ranges usually from 4 to 7 in., increasing by half-inches.

NOTES

Owing to the large area of the face, the force of the blow is distributed over a considerable area. The material of which the head is composed, not being so hard and unyielding as steel, does less damage to the surface of the work when a blow is delivered, i.e. the time of impact is greater.

Mallets are used chiefly for driving chisels, as in mortising, and for knocking wooden frames together.

BLACKBOARD NOTES

HAMMERS

Definition. — Instruments chiefly used for driving nails.

Parts.—

A. *Head.*—Cast steel—Forged to shape—Various patterns. Sketch—Warrington, Exeter, Canterbury, American claw—Vary in weight—weight indicated by numbers.

B. *Face.*—Very hard—slightly curved—less liable to damage surface than if flat.

C. *Pane.*—Very hard—Wedge-shaped—Used for (*a*) straightening bent nails; (*b*) driving nails situated in angles, &c.—Sometimes claw shaped for extracting nails.

D. *Eye.*—Hole through head to accommodate handle—larger at outsides than middle.

No eye in the Canterbury pattern.

E. *Wedge.*—Spreads end of handle—prevents head working loose.

F. *Handle.*—Wood—Ash or Hickory because flexible. Elliptical in section—about 12 in. long—should be comfortable to grip.

End (*a*) tapers in order to pass through eye in head; (*b*) should be held well towards the end.

Axis of head should be in line with axis of nail to be driven.

Blows delivered—three degrees: From Wrist, light—Elbow, heavier—Shoulder, heaviest.

Fig. 233.—B.B. Sketch

BLACKBOARD NOTES

MALLETS

Fig. 234.—B.B. Sketch

Definition.—Instruments used for delivering blows on surfaces which would be damaged if a hammer were used.

Parts.—

A. *Head.*—Wood—Tough beech or hickory—Rectangular in section—Vary in size—Liable to split if handle not perfectly fitted—Mortised to receive handle.

B. *Face.*—Rectangular—Blow distributed over greater area than in case of hammer—Material softer, more yielding than steel of hammer—Time of impact greater—Faces taper towards elbow = face parallel to surface struck.

C. *Mortise.*—Rectangular in section—Tapers towards elbow in length only—width parallel—Inside surfaces must be perfectly flat—handle fits truly.

D. *Handle.*—Wood—Beech—less need for flexible material than in case of hammer, owing to yielding nature of its head—Tapers in width to fit wedge-shaped mortise in head—About 12 in. long—Prevents head flying off by centrifugal motion—Thickness inside the head is uniform to prevent the head splitting.

CHAPTER IX

Miscellaneous Tools

Cork Rubbers.—These are rectangular pieces of cork, usually about 4 in. by 3 in. by 1 in. They are used in conjunction with glasspaper for finishing off the surface of work. The paper is folded over the rubber and the soft texture of the cork enables it to bed down upon the work. Being of cork, no damage is done to the work should the edge of the rubber come in contact with the surface. For small rounded edges or nosings a flute may be formed along the edge of the cork.

NOTES

Cramps.—All forms of cramps are contrivances for holding work together temporarily during the process of working the material or fixing the parts. There are many forms, but the underlying principle in all cases is that of the screw, i.e. the inclined plane.

(*a*) *Small Cramp or G Pattern.*—These consist of a strong rib forged or cast to the form of three sides of a rectangle. One free end is arranged to present a seating for the work, whilst at the other there is a bush which is drilled and tapped to receive a screw. The screw is provided with a seating which impinges upon the opposite side of the work. This seating is not rigidly attached to the screw, but the end of the screw can work freely in the seating or pad. The form of screw varies according to the size of the cramp and nature of the work for which it is intended. For small cramps and light work the V thread is adopted and the power applied by means of a winged or butterfly thumb piece (fig. 235). For heavier work the screw has a "square thread" and the power is applied by means of a lever (fig. 236). The size of such cramps ranges from 3 to 12 in.

Fig. 235

Fig. 236

(*b*) *Bar Cramps.*—The underlying principle of these is similar to that of the foregoing, but in this case, instead of having a rigid frame, they are formed with a rigid bar, which may be rectangular or of T section. The screw attachment for the application of the power is permanently fixed to one end of the bar, and the screws have a square thread. A loose or sliding jaw is provided which can be moved along the bar and held in position by means of a steel pin or by means of a spring pawl which engages with "racking" on the bar. The distance between the jaws can thus be regulated to suit the work in hand. Such cramps are made in all sizes from 18 in. to 7 ft., i.e. length of bar.

When in use, the jaws are apt to damage the surface of the work, which should be protected by means of wooden blocks. If the surface of the bar

is "racked", this also tends to damage the surface of the work, which should be protected by means of thin slips of wood.

Bench Holdfasts.—These are useful for holding work flat on the surface of the bench.

They consist of a stiff rod, at the top of which an arm projects at right angles and carries a forked joint in which a curved arm works on a pivot. The curved arm "lever" is actuated by means of a screw, and the lower end impinges on the work. The pad at the base of the arm is roughened to enable it to grip the work, and care must therefore be taken to protect the work by means of an intermediate piece of wood. The main rod passes through a hole in the surface of the bench and is kept in position by the friction between the material of the bench and the rod. Fig. 237 shows the tool in operation.

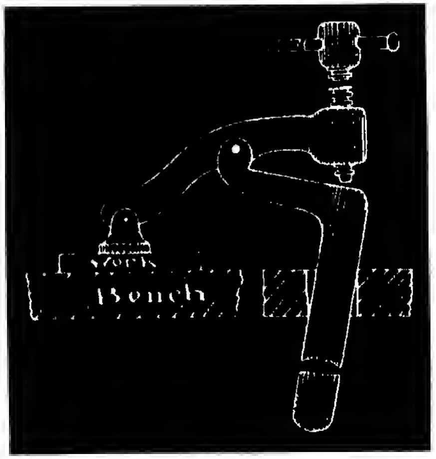

Fig. 237

Files. — These are instruments used for abrading the surface of the material. They are made in a great variety of shapes, sizes, and degrees of cut, and are of very hard cast steel. The blanks are first forged to shape, and before being hardened the "teeth" are formed by the agency of specially constructed file-cutter's chisels. The degree of cut will depend upon the spacing of such chisel cuts and the depth to which the chisel is driven. The first series of cuts forms edges; the second series of cuts arranged diagonally to the first, causes points to be formed. When the cutting is complete the files are hardened.

Oilstones.—A very essential article in the manual-training room is a "good" oilstone. Good work cannot be produced unless the cutting tools are kept in good order and sharp. For the sharpening of all "edge" tools an oilstone is essential. Many varieties of stone are used for the purpose.

They should be of fine grain, uniform in texture, and free from hard veins and specks. That known as the "Lily White" Washita is perhaps one of the most suitable for manual-training purposes. Though it does not produce the keenest of cutting edges, still it is a fairly fast-cutting stone and produces a satisfactory edge. The quality of a stone can be approximately tested by rubbing the thumb nail on the surface and noting the amount of wear. Small quantities of non-drying oil, such as sweet oil or neat's-foot oil, should be used during the process of sharpening. The oil prevents the tools becoming heated during the process of rubbing, with consequent loss of temper at the cutting edge; it further prevents the pores of the stone becoming clogged with the particles of steel removed from the tool. Care should be taken to prevent the surface of the stone becoming clogged with dirt, particularly particles of grit, and for this reason it is essential that the stones should be cased. A convenient size of stone is about 9 in. by 1¾ in. by 1¼ in.

When sharpening chisels and plane irons it is not advisable to rub the "face" of the tool on the stone; and the fine "wire edge" formed during the process of sharpening should be removed by stropping the tool on a piece of "buff leather".

Oilstone Slips.—These are merely thin pieces of oilstone specially shaped for sharpening such tools as cannot be sharpened on the flat surface of an oilstone, such as gouges, spokeshaves, centre bits, carving gouges, and cutting irons of bead planes.

Punches.—These are made from bars of cast steel of small section. They are usually about 4 in. long, having one end drawn down to small section—either round or rectangular—to suit the particular group of nails for which they are intended. The end is roughened or ground to afford a good grip on the heads of the nails.

When the surface of a piece of work which has been nailed together has to be "cleaned off" with a plane, it is essential that the heads of all nails be driven below the surface level.

When the surface is subjected to continual wear, as in the case of a floor, the nails must be "punched"—driven below the surface—otherwise the wood, being softer than the nails, would wear away and leave the heads exposed in an unsightly and dangerous manner.

Again, when the work has to be painted, punching the nails enables the painter to "stop" the hole with putty or other form of stopping, and thus, when the work is painted, it presents an even surface.

Rules.—These need no special description. Many and various kinds are

on the market. Probably the most suitable for manual-training purposes is the two-foot, twofold, engine-divided steel rule, known as "Rabones No. 1644". This rule has the English divisions on one side, whilst on the other will be found the metric scale.

The disadvantages of wooden rules are their thickness and tendency to break.

Screwdrivers.—These are used for "driving" screws into, or out of, the work. They are made in various forms, but the principles of construction are the same in all. There are two principal parts: the handle and blade.

The handle is shaped to afford a comfortable grip and the greatest possible leverage. Hence the top part is elliptical in section, whilst the lower part, near the ferrule, is circular. The ferrules are much thicker than those used for chisels. This is essential, because they are subjected to circumferential compression on the abutments of the slots into which the blade of the screwdriver is fitted.

Fig. 238

By means of the locking arrangement the rotary force exerted on the handle is transmitted to the blade and then to the screw without the blade working loose or remaining stationary whilst the handle is turned, as would happen if the blade were connected to the handle in the manner adopted for chisels.

Two patterns are in common use (fig. 238): (*a*) The London pattern; (*b*) cabinet pattern.

The London pattern has a flat blade, which cannot be conveniently held in the manner just described.

The cabinet pattern is spindle-shaped in the centre of the blade. This enables it to be guided by the hand and turned without inconvenience to the guiding hand.

Screwdrivers are made in various sizes and lengths, from 3 to 12 in. being common. Convenient sizes for manual training are 7 and 4 in. The size is represented by the length of the blade.

CHAPTER X

Notes of a Lesson on the Grindstone and Grinding

Introduction.—You have all seen a plane iron or a chisel sharpened. Notice the difference between these two chisels, one of which is "thin" and the other "thick", and obviously in need of grinding. [Point to sharpening bevel of each.] How is it that one is so much broader than the other? Which will occupy most time to sharpen? Which will require most effort to sharpen? Which do you suppose will cut best and cleanest, even when thoroughly sharp? [Give a demonstration of the cutting power of each.] What must be done to the thick chisel in order to make it cut equally well with the thin chisel?

Cutting Action of Grindstone and Oilstone Compared.—[Point to "grinding bevel" on each chisel. Call attention to its rough surface compared with smooth surface, as left from the oilstone.] Do you suppose this rough surface was produced on the oilstone? Suppose we wish to make this chisel thin, will it do to rub it on the oilstone thus? [Rub the grinding bevel on the oilstone.] What objection do you see to this method? "Slowness of cutting action of the oilstone, and consequent time occupied." Can any boy suggest a method by which this chisel can be made thin much more quickly than by rubbing it on the oilstone? "By grinding."

Composition and Shape of Grindstone.—[Call class round the grindstone.] What material is this? Point to the stone. [Allow class to test the surface with their finger nails.] What is the nature of this stone? What is this substance? [Exhibit "sand" from the stone.] What kind of stone is this? "Sandstone." What is the shape of these surfaces—pointing to circular sides? What is the shape of the solid? "Cylindrical."

The Axle and Crank.—You have all seen the wheels on a cart. What is the bar of iron which joins the wheels called? What would you call this piece of metal on which the stone revolves? "Axle." How is the stone turned? "By the handle." You have called this the handle. Have you seen anything like it on a bicycle? What part of the bicycle do you call it? "Crank." What might this particular form of handle be called? [Ask class for other examples of the use of cranks. Refer to crank on brace, &c.]

Leverage of Crank.—Could you turn this stone if there was only the straight axle? What is the object of this crank formation? Suppose it was found very difficult to turn the stone with a very short crank, what could be done in order to make it easy to turn the stone? [Explain meaning of short and long crank, i.e. crank arm. "More leverage." Refer to handle in bench screw.] What do you do if the screw is at all tight? Why do you pull the handle farther through? [Explain: "Leverage".] What is obtained in the case of this grindstone by means of this crank?

Brake Action of Tools Ground.—We will endeavour to discover why it is necessary to have so much leverage for turning the grindstone. At what part of the stone does the actual grinding take place? [Fix the chisel in grinding attachment "if any", and press it on the stone whilst one of the scholars turns the stone.] How does the driver of a cart stop the cart when he wishes to? What is this "thing"

which is pressed on the wheel called? [Refer to brake on a bicycle.] How is it that it is easy to stop the wheel revolving by pressing on the rim? "Great leverage." What is the chisel acting as whilst it is being pressed on the revolving stone? [Give illustration of ease with which it is possible to prevent the scholar from turning the stone by simply pressing down the "levers" of the grinding attachment.] Why is it necessary to obtain so much leverage by means of the crank in order to turn the stone? "Owing to great resistance offered to rotation of stone by chisel being pressed upon the surface."

Necessity for Using Water.—(*a*) *Friction and Heat.*—If you rub your hands together very quickly, what do you feel? What happens if any two substances are rubbed together quickly? What do you suppose will happen if the stone is revolved very quickly and the chisel held in contact with it? [Explain that if a piece of steel is made hot, and allowed to cool slowly, it becomes soft.] What will happen to the chisel if it is made hot in the manner indicated, and allowed to cool slowly? Will it remain sharp for any length of time once it has become soft? How can this heating of the chisel be avoided? What is the object of allowing water to drip on the stone?

(*b*) *Choking of Pores.*—[Rub the chisel on the surface of the grindstone before wetting the stone Ask scholars what they observe concerning the place where the chisel was rubbed. Elicit: "Black and shiny".] What has made the surface black? "Particles of steel." [Allow boys to feel the blackened surface.] What do you notice about this surface? "Smooth." Will the stone continue to grind—"abrade" [Explain term "abrade"]—if the surface is allowed to become smooth? How can this be prevented? What two reasons have we for keeping the stone wet whilst grinding?

Condition of the Surface of Grindstone.—[Call attention to necessity for keeping the surface of the stone straight from side to side. Allow scholars to see the chisel being moved from side to side of the stone as the grinding is in process.] What is the object of this? Can you now explain why this frame in which the chisel is fixed is so loose in the joints?

Grinding Angles.—[Call attention to the angle which the grinding bevel makes with the face of the chisel—"about 25°"; also to angle between sharpening bevel and face—"about 35°". Educe reason for this difference.] What objection do you see to grinding the chisel as thin as a razor? Would it be strong enough for cutting wood? Would the chisels which are used for cutting wood be strong enough for cutting metal? Why are these particular angles adopted? [Explain that experience has led to the adoption of these particular angles, it having been found that they are most suitable for working in wood. The angle varies in cutting instruments according to the nature of the material to be cut. Exhibit various samples of cutting tools if possible.]

[The plumber blocks, trough, foot-driving attachment, if any, could be made the subject of subsequent lessons.]

NOTES

BLACKBOARD NOTES

Necessary to grind chisels and plane irons after they have been sharpened several times.

Grindstone.—Composed of particles of sand naturally cemented together = Sandstone.
Surface rough—abrades steel more quickly than the "finer grit" of oilstone.

Handle.—A form of crank—Gives greater leverage.

Water.—(*a*) Keeps chisel cool prevents chisel becoming soft—preserves cutting power.
(*b*) Keeps stone clean—washes away fine particles of steel.

Angles for Grinding.—About 25°.
Varies in other cutting tools, according to material to be cut.

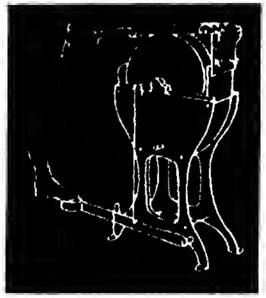

Fig. 239.—B.B. Sketch

CHAPTER XI

Blackboard Notes on Various Tools

PINCERS

Definition.—Instruments used chiefly for extracting nails which have become bent in driving, and for obtaining a firm grip on small articles.

Construction.—Composed of two arms, "levers", A, B, working on a rivet, "Fulcrum", sufficiently loose to admit of movement.

Parts.—A, B. *Arms* or "Levers".—Steel—Forged to shape—finished by filing and grinding.
C. *Rivet*, "Fulcrum".—Connect arms.
D. *Jaws*.—Hardened steel—Fairly sharp—Grip nails.
E. *Space*.—Accommodate head of nails, &c.
F. *Claw*.—Wedge-shaped and forked—for levering boards, lifting tacks, &c.

(See Part I, Chapter XI, for mechanical principles involved in construction and when using same.)

Fig. 240

Fig. 241

Fig. 240 shows the various parts; fig. 241, method of using.

SPECIAL BITS

Expansion Bit.—Combination of auger bit and centre bit—Can be set to bore hole of given diameter—Usually supplied with two cutters—Size of hole, $\frac{7}{8}$ to 5 in.—Useful for sinking inkwells, &c. (Fig. 242.)

Fig. 242

Forstner Auger Bit (Catalogue description).—This labour-saving auger bit, unlike other bits, is guided by its periphery instead of its centre, consequently it will bore any arc of a circle, and can be guided in any direction regardless of grain or knots, leaving a true polished surface; therefore it is preferable to and more expeditious than chisel, gouge, scroll saw, or lathe tool combined for core boxes, fine and delicate patterns, veneers, screenwork, scalloping, fancy scroll, twist columns, newels, ribbon moulding, mortising, &c. (Fig. 243.)

Fig. 243

SPECIAL FORMS OF BRACE BITS

COUNTERSINKS

Explain the term "countersink". Call attention to necessity for same, in order to enable heads of screws to bed into wood, iron or brass.

A. **Wood Countersink or Snailhorn Bit** (for Wood).—Form of cone—Fluted—One simple cutting edge presented to the wood.

B. **Flat Countersink** (for Iron).—Scraping action—Two edges presented to metal. Note "angle of clearance".

C. **Rose-headed Countersink** (for Brass).—Conical in form—Many cutters—Scraping action—Cutting uniformly distributed. (Fig. 244.)

Fig. 244

TURNSCREW

D. **Simple.**—In form of ordinary screwdriver—Used with brace—continuous rotary motion—Greater leverage.

E. **Forked Bit.**—Slot in centre—Used for tightening nuts on saw bolts. (Fig. 245.)

Fig. 245.

SIMPLE FORMS OF BRACE BITS

A. **Spoon Bit.**—For ordinary boring.
B. **Shell Bit.**—For ordinary boring.
C. **Nose Bit.**—Dowelling and end-grain boring.
D. **Swiss Bit.**—Ordinary use—Draws and clears better than previous bits.
E. **Auger Bit.**—Bores cleaner holes—Acts to greater depth—Size of hole much

truer—Removes core owing to spiral twist—Screw point enables them to draw with ease—Suitable for larger holes—Size, ¼ to 1 in., sometimes larger. (Fig. 246.)

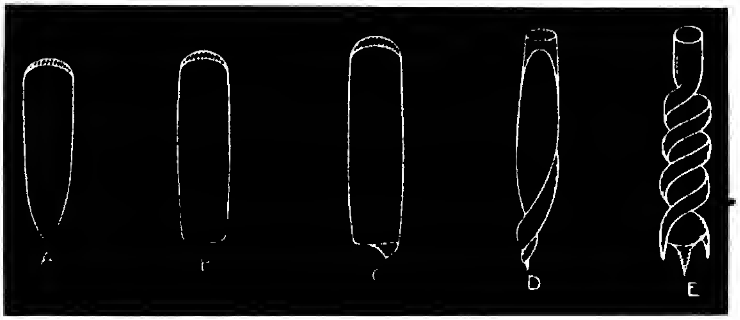

Fig. 246

NOTE.—When giving a lesson on these, lead the scholars to compare and contrast, and note the action of each as the lesson proceeds.

CENTRE BITS

Definition.—Instruments used in conjunction with the brace for boring holes—Size varies, ¼ to 2 in. by sixteenths.

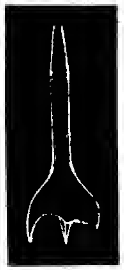

Fig. 247

Construction.—Forged to shape from cast steel—Filed, ground, hardened, and tempered. (Straw colour = best.)

Parts.—(Fig. 247.)—

The Shank.—Enlargement near top to fit recess in jaws of brace.
Blade.—Drawn out to suit size of bit.
Centre Pin.—Triangular in section—Controls motion of bit—placed at centre of hole.
Vertical Cutter.—Cuts fibres at circumference of hole.
Horizontal Cutter or Lip.—Removes core—Shavings in spiral form.

Method of Sharpening.—Filed with smooth file, finished with oil-stone slip. The vertical cutter should be slightly curved, to enable it to glide over the fibres.

Part III

PRACTICAL WORK

INTRODUCTION

This section contains a systematic course of exercises destined to provide ample practice in tool manipulation, and afford opportunity for the introduction of the many lessons which help to make manual training a factor in education.

The method of sharpening tools and keeping them in order is very important, because, if satisfactory work is to be executed, it is essential that they be kept in good condition, and the sooner students learn to perform for themselves the various operations involved, the better it is for teacher and scholar.

As far as possible the tool processes have been arranged in progressive sequence. The examples in the preceding section are taken from the various exercises in the present section.

The great difficulty which presented itself was that of selecting suitable exercises from the great variety which woodworking affords. It will be seen that in most cases the exercises represent complete articles having some distinct value. Joint-making and exercises introduced for the mere purpose of imparting a knowledge of tool manipulation find no part in such a course. Experience has shown that children delight in making some article which they know to have a definite use, and which use readily appeals to them. It is this fact which the teacher should seize upon and use as a means of securing the greatest interest, zeal, and attention of his scholars.

Many of the models are extremely simple in character. This, upon reflection, is a merit rather than a demerit, for to be truly successful manual-training exercises must be such that each scholar can complete any given one without direct aid from the teacher. This can be accomplished when the early exercises are simple in character and lead gradually by simple steps to the more difficult operations.

It is often urged that teachers should not be bound by any hard-and-fast course of work, and with this all who have experience of the work will agree. Yet all must have some course which shall form the backbone of the system,

NOTES

and as experience is gained such system will be enlarged upon or modified to suit any special requirements.

The teacher who starts out with no system, no method, may for a time appear to succeed, but sooner or later will come to a standstill. There will be no continuity of progress, and there is usually overlapping in the arrangement of the work.

It is also often urged that the scholars should carry out all sorts of operations in the way of making and repairing articles of furniture and appliances for demonstrating experiments in the schoolroom, such work being regarded in the sense of "correlation". Against such methods a strong protest should be uttered. The work of the manual-training class should no more be interfered with than the arithmetic lessons or geography lessons in the classroom. The manual-training teacher must assume full control and allow no intrusion. The making of simple apparatus can be considered only when the article desired can be converted into an exercise for the class. There is usually either much that is too simple or much that is too difficult in such requirements, with the result that the scholars are wasting time, or the teacher is wasting his time in carrying out those exercises which are beyond the capacity of the scholar. The introduction of such work tends to disorganize the work of the class, and the gain in one direction does not compensate for the loss in other directions. This is no idle expression of opinion. It is a statement of fact based on experience.

This section has been arranged in three groups, representing presumably three years' work, but this must not be taken too literally.

The amount of time allotted to the work is a very important factor. Unfortunately one hears on all sides that the curriculum is overloaded, and consequently the time given to this subject is reduced to an unsatisfactory minimum. For scholars to reap the greatest benefit from such a subject it is essential that the minimum time be three hours per week.

When speaking of manual training it must be remembered that the term comprises more than one subject. Drawing plays a very important part in the course, and demands the expenditure of a considerable fraction of the time. Demonstrations given by the teacher have a more far-reaching effect than is commonly attributed to them. It is here that the scholars have their power of observation developed. The scholars have to observe their teacher at work, and note his every action. It is the teacher's *actions* that must be

observed, the words he utters during such demonstrations should be of secondary consideration; in fact, a good demonstration should require but few or no words. Such silent teaching takes considerable time, and it must be borne in mind that it is the teacher who is working, not the scholars, during such demonstrations.

A further demand is made upon the time devoted to the subject for the purpose of object lessons upon tools and timber, all of which are important as factors in the further development of the child's power of observation, and serving as a lesson on oral composition. All things considered, little time is left which the scholars can actually devote to "production". It is this fact which tends, more than anything else, to lead the uninitiated to condemn manual training. There is a tendency to measure the value of the subject by the amount of *production*, not by the amount of training which the scholars have received. Superficial show is all that some people expect of manual training. The true teacher will not take this view, but, having a certain amount of time allotted to his subject, will seek to subdivide that time in such a manner that the scholars receive the greatest good for a minimum expenditure of time. He will conscientiously leave production to take care of itself.

Having considered these points, it is clear that unless some unworthy sacrifice is to be made, no attempt should be made to define the actual amount of production which must take place in any class. A good teacher will aim at accomplishing a certain task in a given time, and if he be a "good teacher" and knows his class, he will not go far wrong in framing his estimates. Scholars should therefore be allowed to work steadily through the exercises as arranged, except for those modifications which the teacher may deem necessary from time to time. Particularly is this important for the first two groups. In the third group scholars might be allowed to make selections, subject to the approval of the teacher.

It will be seen that with every exercise a list of the tools and material required is given. This, and the method of dealing with such, is important. The scholars must not be "told" what tools and material will be required. They must be trained to analyse each piece of work and discover the various processes involved, and thus determine the various tools required to carry out each operation. They must be trained to discover from their drawings the quantity of material required for each part of the work. This method

occupies more time than the "mere telling"; but again the fact should be emphasized that the child is to be trained to think and to reason, therefore it is time well spent.

The demonstrations are suggestive only. Each teacher must decide for himself what it is necessary to demonstrate, when such demonstrations are necessary, and how much he will demonstrate in any one lesson. This will largely depend upon the ability and mental capacity of the scholars. There is usually a tendency with young inexperienced teachers to overload the early demonstrations, and to express surprise that the children have not grasped all the details. How often one hears the expression, "That is not how I showed you to do it". What is the cause of this? Usually over-demonstration.

Remember that the acquirement and assimilation of knowledge is a slow process. Make your demonstrations short; let them be definite; use as few words as possible; repeat your demonstrations only where your actions have been misunderstood.

Another common mistake is that of demonstrating operations which are familiar to the pupils. This should be avoided. It is frequently the case that teachers will demonstrate planing with almost every model. What waste of time! Demonstrate only those processes which are not understood.

The method of treating the lessons on tools, timber, and miscellaneous material is fully discussed.

In most cases a few simple problems have been included after each exercise.

In conclusion, all teachers of manual training should set themselves a very high standard. A high aim and conscientious work will carry conviction. Actions will speak louder than words.

NOTES

COURSE I

EXERCISE I

MARKING OUT, SAWING, AND CHISELLING

Exercises Involved.—Marking out. Sawing. Gauging and chiselling: (*a*) at right angles to the grain; (*b*) oblique to the grain.

Instructions.—

DRAWING.—Prepare a plan and side elevation.
Write out a list of the tools and material required.

NOTE.—It cannot be assumed that the scholars know the names of any of the tools that will be required for this exercise. It will therefore be necessary for the teacher to state the names of such tools and write them on the blackboard. In subsequent lessons the scholars should be trained to think out the various stages in the execution of any given exercise and the tools that will be necessary to carry out each stage, the teacher supplying the name of any new tool that will be required.

The list of tools should, as far as possible, be arranged in the order in which they will be used in the execution of the work.

Tools Required.—Ruler. Pencil. Marking knife. Try square. Marking gauge. Tenon saw. Firmer chisel.

Material Required.—Red pine, clear pine, or poplar. All are suitable for this exercise.

NOTE.—As it is not intended to teach planing in this exercise, each scholar should be supplied with a piece of wood planed true to width and thickness, the length being slightly in excess of the finished model.

Benchwork.—STAGES.—

1. Select and mark the face side and face edge.
2. Mark off length and draw the square lines across the surface.

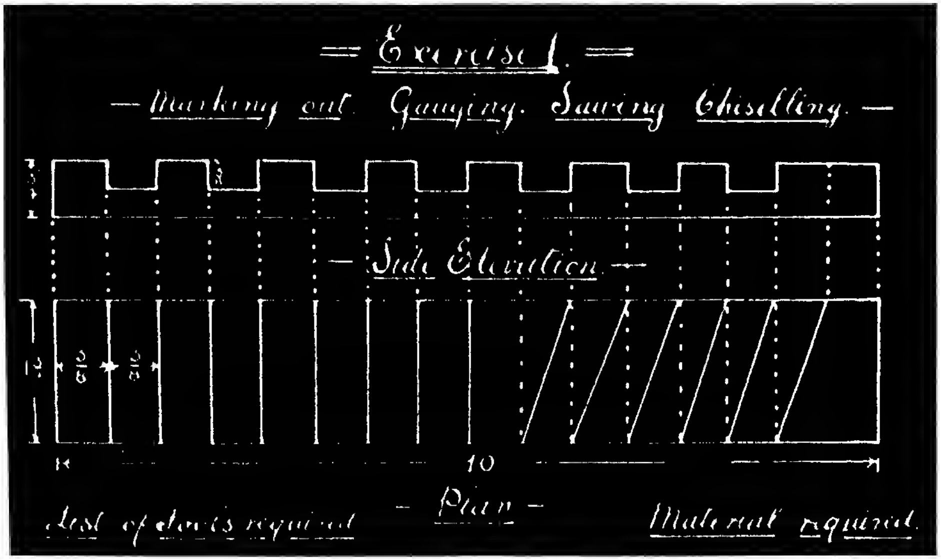
Exercise 1.
Marking out. Gauging. Sawing. Chiselling.
Side Elevation.
2"
10
Plan
List of tools required
Material required.

Fig. 242

NOTES

3. Set out the ¾-in. divisions, using the scribing knife for the first half and the pencil for the remaining portion.

4. Draw square line across the surface, using the scribing knife and pencil as in 3.

5. Draw oblique line across the right half of the model, as shown in drawing.

6. Gauge the depth of the grooves.

7. Saw the sides of the grooves.

8. Remove waste from grooves with chisel.

9. Test all dimensions with the rule, also compare the finished model with the drawing.

Demonstrations.—

1. Selecting and marking face side and face edge.
2. Marking off dimensions.
3. Using the try square.
   (*a*) For drawing lines at right angles to a face of the material.
   (*b*) For drawing lines oblique to a face of the material.
4. Setting and using the marking gauge.
5. Securing the work for the purpose of sawing.
6. Holding and using the tenon saw.

NOTE.—Particular attention should be paid to the general arrangement of the work in the vice.

7. Fixing the work in the vice for the purpose of removing the waste from the grooves.

8. Holding the chisel and removing the waste from grooves which are at right angles to the side of the material.

9. Holding the chisel and removing the waste from the grooves which are oblique to the sides of the material.

10. Testing the dimensions, flatness of grooves, and comparing the finished work with the drawing.

Remarks on Tools.—It will be quite sufficient, for this lesson, to name the tools used and draw attention to the correct method of holding each.

Remarks on Timber.—Tell the scholars the name of the wood that is being used for the exercise, and instruct them to observe such points as—(*a*) colour; (*b*) peculiar markings; (*c*) nature of the wood as disclosed by sawing and chiselling.

EXERCISE II

PLANING

Exercises Involved.—*Marking out on plank. Long sawing. Face planing. Edge planing. Gauging to width. Planing to width. Gauging to thickness. Planing to thickness.* Marking out. *Chiselling vertically. Chiselling obliquely,* i.e. *chamfering across the grain. Boring.* Sawing across the grain.

Instructions.—Drawing.—Prepare a plan and side elevation of each portion. Write out a list of the tools and material required.

Tools Required.—Ruler. Pencil. *Straightedge. Panel saw. Jack plane.* Try square. Gauge. Marking knife. Tenon saw. Firmer chisel. Brace. ⅜-in. *centre bit.*

Material Required.—One piece of clear pine, poplar, or red pine 13 in. by 2 in. by 1 in.

Benchwork.—Stages.—

1. Mark out plank.
2. Saw out material.
3. Plane a face side.
4. Plane a face edge.
5. Gauge the wood to width.
6. Plane the wood to width.
7. Gauge the wood to thickness.
8. Plane the wood to thickness.
9. Mark out as shown in drawing.

Note.—Use a pencil for the chamfer lines. Mark the centres of the holes: do not draw the circles.

10. Saw off the waste at each end.
11. Vertically chisel corners at right end of model.
12. Make chamfers at left end of model.
13. Bore the holes.
14. Saw the model into the two component parts.
15. Chamfer the ends of each as in Stages 11 and 12.
16. Test all dimensions and compare the finished work with the drawing.

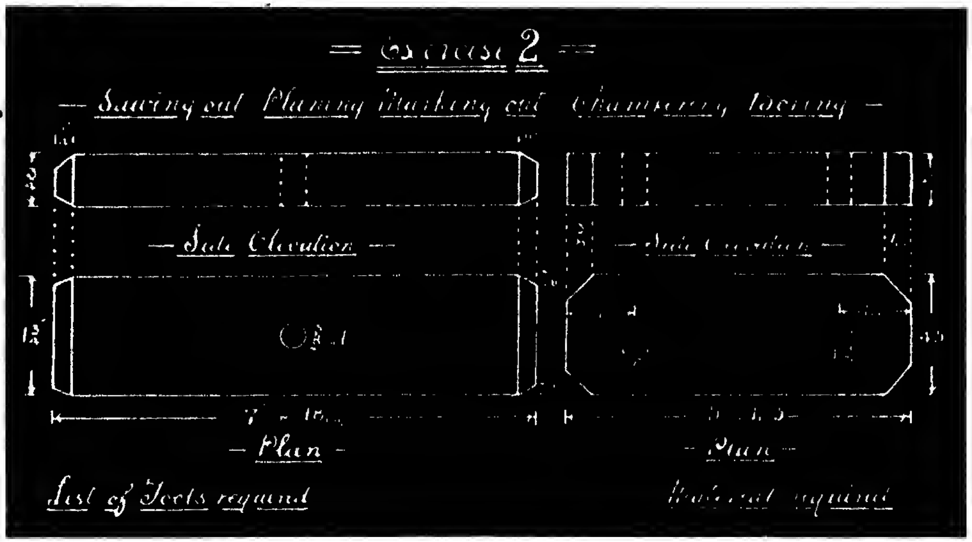
Exercise 2
Sawing out Planing Marking out Chamfering Facing
Side Elevation
Plan
Plan
List of Tools required

Fig. 249

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Demonstrations.—

1. *Marking out and sawing the plank.*
2. *Planing in the following stages:—*

(*a*) *Face side.*	(*b*) *Face edge.*
(*c*) *Gauging to width.*	(*d*) *Planing off the waste.*
(*e*) *Gauging to thickness.*	(*f*) *Planing off the waste.*

3. Marking out work from drawing.
4. Sawing off the waste.

NOTE.—Ask simple questions concerning the method of holding and using the saw.

5. *Chiselling vertically.*
6. *Chamfering—Chiselling obliquely.*
7. *Using the brace and centre bit.*
8. Testing the finished work.

Remarks on Tools.—Question concerning the names of the tools used in the first model; the methods of holding them; names of chief parts As·

TRY SQUARE.—Stock—black colour.
Blade—made of steel.
Other metal—brass.
GAUGE.—Stem—long piece.
Stock—large piece.
Spur—part for making the mark.
CHISEL.—Handle—blade.
Metals used—steel and brass.
TENON SAW.—Handle—blade.
Metals used—steel and brass.
The new tools used will have been named during the demonstration.

Remarks on Timber.—Compare with wood used for Exercise I. Simple questions concerning the colour and nature of the wood. What is the colour of the wood? Does the wood plane easily? Could you chisel the wood easily? Is it hard or soft to the touch? Is the gauge made of the same kind of wood? Is the stock of the try square made of the same kind of wood? Is any part of the bench made of the same kind of wood? Can you see any articles in the room which are made of the same kind of wood?

EXERCISE III

KEY OR LUGGAGE LABELS

Exercises Involved:—Marking out plank. *Long sawing—thin material.* Chiselling vertically: (*a*) a straight surface; (*b*) *a curved surface. Chiselling obliquely.* Boring. *End-grain planing.*

Instructions.—Prepare a plan and side elevation of each portion.

Call attention to the method of constructing the octagonal end of the luggage label, also the Gothic curve which is based on the equilateral triangle.

Tools Required.—Ruler. Pencil. Straightedge. Panel saw. Jack plane. Try square. Gauge. Marking knife. *Compasses.* Tenon saw. Chisel. Brace. ⅜-in. centre bit. *Shooting board. Smoothing plane.*

Material Required.—One piece of clear pine or poplar, 12 in. by 2½ in. by ½ in.

Benchwork.—Stages.—

1. Mark and saw out material.
2. Plane material to required dimensions.
3. Mark out work as shown in drawing.
4. Saw off waste at each end.
5. Obliquely chisel end of first label.
6. Vertically chisel curved end of the second label.
7. Separate the parts, sawing a short distance from the line to allow for "shooting" the ends.
8. Plane the ends on the shooting board, i.e. "shoot the ends".
9. Vertically chisel the corners.
10. Bore the holes.
11. Clean the surfaces with the smoothing plane.
12. Test all dimensions and compare the finished work with the drawing.

Demonstrations.—

1. Marking out the plank, sawing out the material and planing to dimension.

Note.—Question the scholars, as the work proceeds, concerning the various stages to be executed, as detailed in the previous lesson.

2. Marking out work from the drawing.

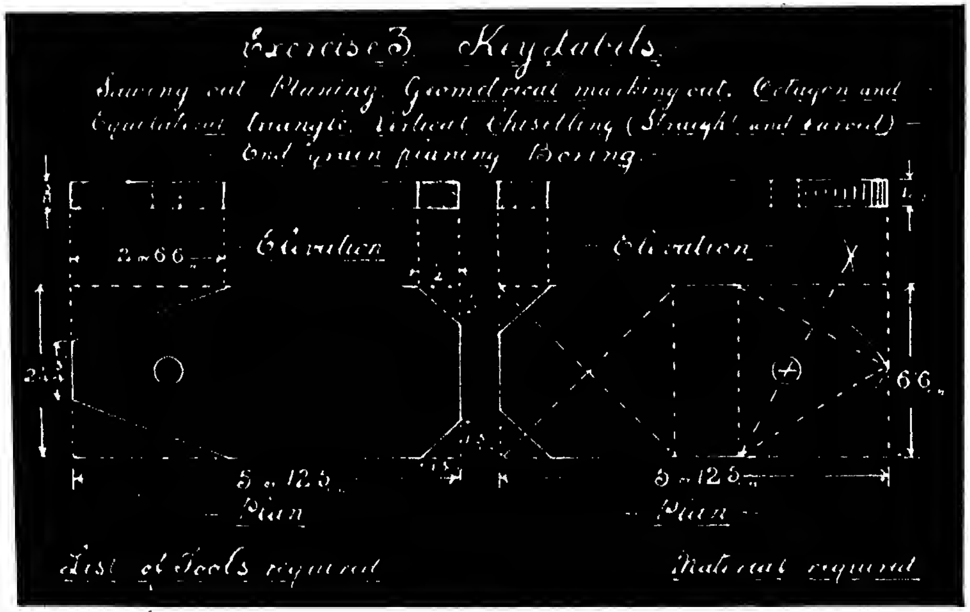

Exercise 3. Key labels.
Elevation
Elevation
Plan
Plan
List of Tools required
Material required

Fig. 250

3. Sawing off the waste and *obliquely chiselling one end.*
4. *Vertically chiselling curved end.*

NOTE.—Work from base of curve towards the apex. See remarks in Part II, Chapter VI, on the "wedge action" of the chisel when performing chiselling of this kind.

5. Boring the holes.

Question the scholars concerning the various points dealt with when giving similar lesson in previous model.

6. *Separating the parts, allowing for "shooting" of ends.*
7. Vertically chiselling corners.
8. End-grain "shooting".
9. *Using smoothing plane to clean surfaces.*
10. Testing the finished work.

EXERCISE IV

A KEYBOARD

Exercises Involved.—Marking out on plank. Long sawing at vice. Planing to dimensions. Geometrical marking out of ends. Sawing with tenon saw. Vertical chiselling. Chamfering with chisel across the grain. *Chamfering with chisel oblique to grain. Chamfering with jack plane. Boring with bradawl. Use of smoothing plane. Nail driving to special angle.*

Instructions.—DRAWING.—Prepare a plan and elevation as shown. Call attention to special shape of the ends and the method of constructing the octagon, which should be carried out as follows:—

(*a*) Draw the squares at each end.
(*b*) Draw diagonals of squares.
(*c*) Draw the quadrants, using the corners of the square as centres, and having the compasses set to half the length of the diagonal for radius.

NOTE.—There is a common tendency among scholars to treat this construction somewhat carelessly. The curves (quadrants) should just touch back to back, in the centre.

Draw attention to projection of inclined intersection of chamfers. Treat their extremities as points, and deal with these as described in the chapter on "Projection".

Question concerning the tools and material necessary, and fill in the lists.

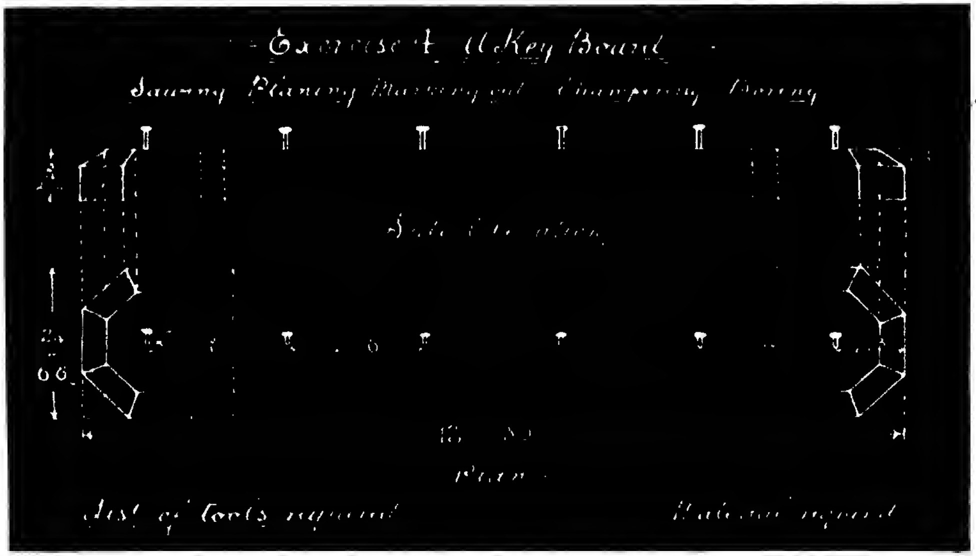


Fig. 251

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Try square. Gauge. Marking knife. Compass. Tenon saw. Firmer chisel. Brace and ⅜-in. centre bit. *Fine bradawl.* Smoothing plane. *Hammer.*

Material Required.—One piece of clear pine or poplar, 13 in. by 2½ in. by 1 in.; six 1¼-in. brass escutcheon pins, or six 1- or ¾-in. brass square-shouldered hooks.

Benchwork.—STAGES.—

1. Mark and saw out material.
2. Plane material to required dimensions.
3. Mark off length and set out ends and centres for holes and nails.
4. Cut off waste and vertically chisel corners.
5. Chamfer (*a*) ends, (*b*) oblique corners, (*c*) long edges. (Use jack plane.)
6. Bore the holes, and with bradawl prick holes for nails or hooks.
7. Clean off surfaces with smoothing plane, and drive in nails or insert hooks.
8. Test finished work and compare with drawing.

Demonstrations.—

1. Marking out and sawing plank.

2. Planing to dimensions. Question concerning stages to be gone through when planing.

3. Marking out work from drawing.

NOTE.—In order to use the compass for constructing the octagons at the ends it will be necessary to place an odd piece of wood against the side of the exercise, in order that the point of the compass may rest on the joint, as shown at *a* and *b* in accompanying fig. 252.

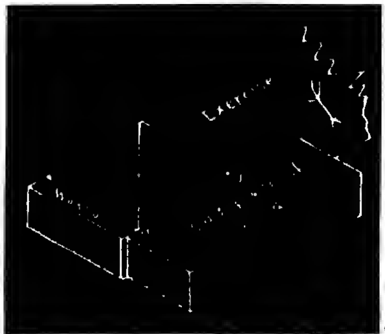


Fig. 252

4. Sawing off waste and vertically chiselling corners.

NOTE.—It will be sufficient to saw one end and chisel one corner. The remaining corners can be executed whilst the pupils proceed with their work,

NOTES

or they can be utilized for demonstrations to weaker boys who have not mastered the detail during the main demonstration.

5. Method of marking out chamfers.

NOTE.—It will be necessary to make a thumb gauge for the purpose. This consists of a small piece of wood 3 or 4 in. long and about ½ in. square, having notches at each end which are respectively ⅜ and ¼ in. long. (See chapter on "Gauging" for details concerning method of making and using.) It is at times convenient to use an ordinary gauge for the purpose. This can be accomplished by moving the stock to the back end of the stem, the stem being allowed to protrude a distance equal to the distance the required line is to be on the surface from the edge of the material, and using a pencil, as in the case of a specially constructed thumb gauge.

6. Chamfering in separate stages: (*a*) The ends, (*b*) the oblique chamfers, (*c*) the chamfers along the edge.

7. Boring the holes. Pricking the holes for the nails. Cleaning the surfaces with the smoothing plane. Driving the nails. Testing finished work.

Remarks on Tools.—Carry the questioning concerning tools used a stage further. Introduce other simple details. Mention parts of hammer.

Timber.—Question concerning details of the material used.

Nails.—Special metal of which composed. Particular colour. Advantage of using brass (does not rust).

EXERCISE V

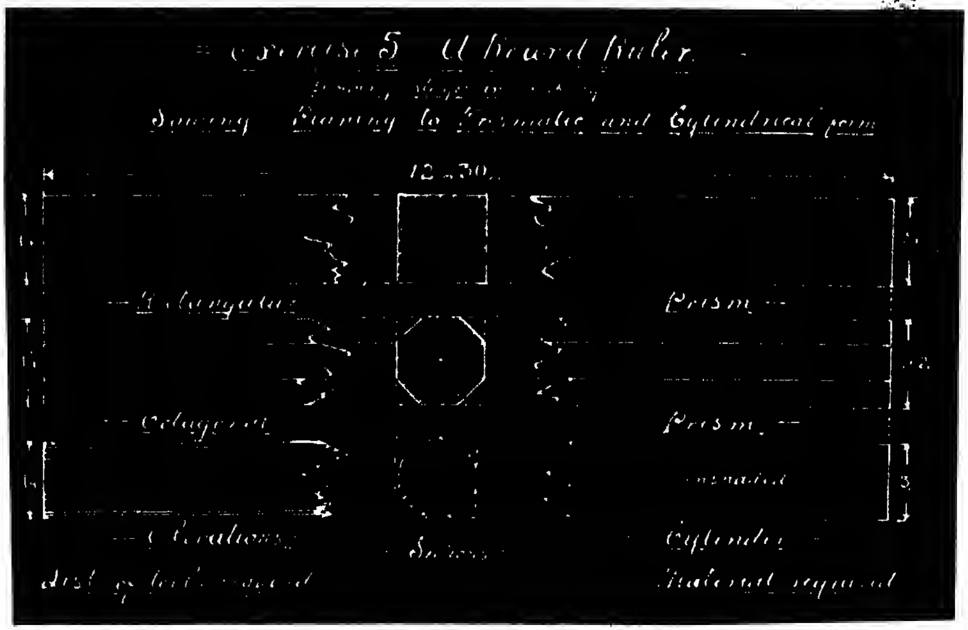
A ROUND RULER

Exercises Involved.—Marking out on plank. Long sawing. Planing to dimension. Cutting to length. *Geometrical marking out on end grain.* Chamfering with plane, i.e. *planing to prismatic form. Planing to cylindrical form. Filing a curved surface. Glasspapering.*

Instructions.—DRAWING.—Prepare a drawing showing the three stages through which the work passes, together with sections or end elevations.

It will be noticed that the sections of the rectangular prism and octagonal prism are slightly larger than the diameter of the cylinder. This allows for the planing, filing, and glasspapering of the cylinder.

NOTE.—When drawing an object the length of which is much greater than its sectional area, and provided it is parallel and of uniform structure through-


Exercise 5 A Board Ruler.
12 x 30
Rectangular
Prism
Octagonal
Prism
Elevations
Sections
Cylinder
Material required

NOTES

out its length, it is not necessary to show the complete length; but the middle portion is assumed to be broken out and the two ends drawn close together to a large scale, as shown in the accompanying figure (fig. 253).

Question concerning the tools and material necessary to execute the work, and fill in the lists.

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Try square. Gauge. Marking knife. Tenon saw. Compass. Smoothing plane. *Half-round file. Glasspaper.*

Material Required.—One piece of clear pine, poplar, or red deal, 13 in. by $1\frac{5}{8}$ in. by $1\frac{5}{8}$ in.

Benchwork.—STAGES.—

1. Mark out plank and saw out material.
2. Plane material (*a*) face side; (*b*) face edge; (*c*) gauge to width; (*d*) plane off the waste; (*e*) gauge to thickness; (*f*) plane off the waste.

NOTE.—The exercise should be carried out in the stages indicated, each scholar submitting his work for approval as each stage is executed.

3. Mark off length and saw off waste.
4. Mark out ends, i.e. draw diagonals and circles, as in section of cylinder.
5. Mark chamfer lines on all surfaces.

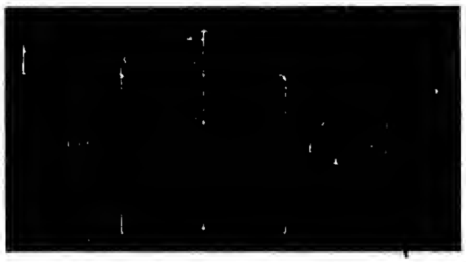


Fig. 254

NOTE.—For this purpose it is necessary to make a "thumb gauge", which can be executed in the following manner: Prepare a small piece of wood about 4 in. long, $\frac{5}{8}$ in. wide, and $\frac{1}{4}$ in. thick ($4'' \times \frac{5}{8}'' \times \frac{1}{4}''$); these dimensions are not important, and need not be adhered to. Next apply the piece to the end of the model, as shown in accompanying figure (254). The end A is placed to the centre of the piece and a mark made at B, so that the distance A B is equal to half the length of the diagonal (*a*). The piece A B is then sawn out, and the top chamfered as shown (*b*). This enables the chamfer lines to be drawn on the surfaces of the rectangular prism. The gauge is held in the left hand and the pencil,

NOTES

applied by the right hand, gauge and pencil being gradually drawn towards the operator. (See chapter on "Gauges and Gauging".)

6. Make chamfers, i.e. convert the rectangular prism into an octagonal one.

7. Plane to cylindrical form.

NOTE.—This should be carried out by systematically doubling the number of faces to the prism, as 8, 16, 32, 64, 128, 256, and in such a way that all faces are of uniform width. It will readily be seen that, as the number of faces is increased, they must of necessity become much narrower, until "theoretically" they become so numerous as to have no width; that is, they form a cylindrical surface. It is essential that the circles on the ends are carefully watched and the lines worked to.

8. *File and Glasspaper.*—It is not possible to produce with a plane having a flat face a perfect cylindrical surface. The file and glasspaper are therefore introduced in order to remove any remaining edges.

As the work proceeds the scholars should test their work by revolving it in the hand, the tips of the fingers being allowed to just touch the surface of the work. Any irregularities are in this way quickly detected, the sense of touch in such cases being keener than the sense of sight.

The filing is executed in the following manner: One end of the model rests on the bench, whilst the other is held lightly between the thumb and finger of the left hand. The file is held in the right hand, and a dual motion imparted to it—i.e. forward in direction of axis of file, and downwards along the model. The model is at the same time rotated by the left hand. These two motions combine to produce the true cylindrical surface.

Demonstrations.—

1. Marking out plank, sawing, and planing.
2. Marking out work and sawing off waste.
3. *Marking ends and chamfering to octagonal form.*
4. *Planing to cylindrical form.*
5. *Filing and glasspapering.*
6. Testing the finished work.

Lessons.—Deal with special form of *Solids*: (*a*) regular, (*b*) irregular.

Irregular solids have no special shape, as a lump of stone, &c.

Regular solids (*a*) have a special shape;
(*b*) named after their shape and arrangement of surfaces.

The Sphere.—A ball. All points on surface equidistant from a given point within, called the "centre".

Prisms.—Solids the faces of which are parallelograms and the ends equal and parallel figures.

(*a*) Right prism—ends at right angles to axis.

(*b*) Oblique prisms—ends parallel but inclined to axis.

Prisms named after the shape of their ends, as: square, rectangular, triangular, pentagonal, hexagonal, octagonal, &c.

Cylinder.—An elongated, round, solid body of uniform diameter throughout its length, and terminating in two flat circular surfaces which are equal and parallel.

Pyramids.—Contrast with prisms. A solid whose base is a rectilineal figure, and whose sides are triangular and meet in a point.

(*a*) Right pyramid—axis at right angles to base.

(*b*) Oblique pyramid—axis is inclined to base.

(*c*) Named after shape of base, as: triangular, square, rectangular, pentagonal, hexagonal, octagonal, &c.

The Cone.—A solid having a circular base and tapering to a point.

(*a*) Right cone—axis at right angles to the base.

(*b*) Oblique cone—axis inclined to the base.

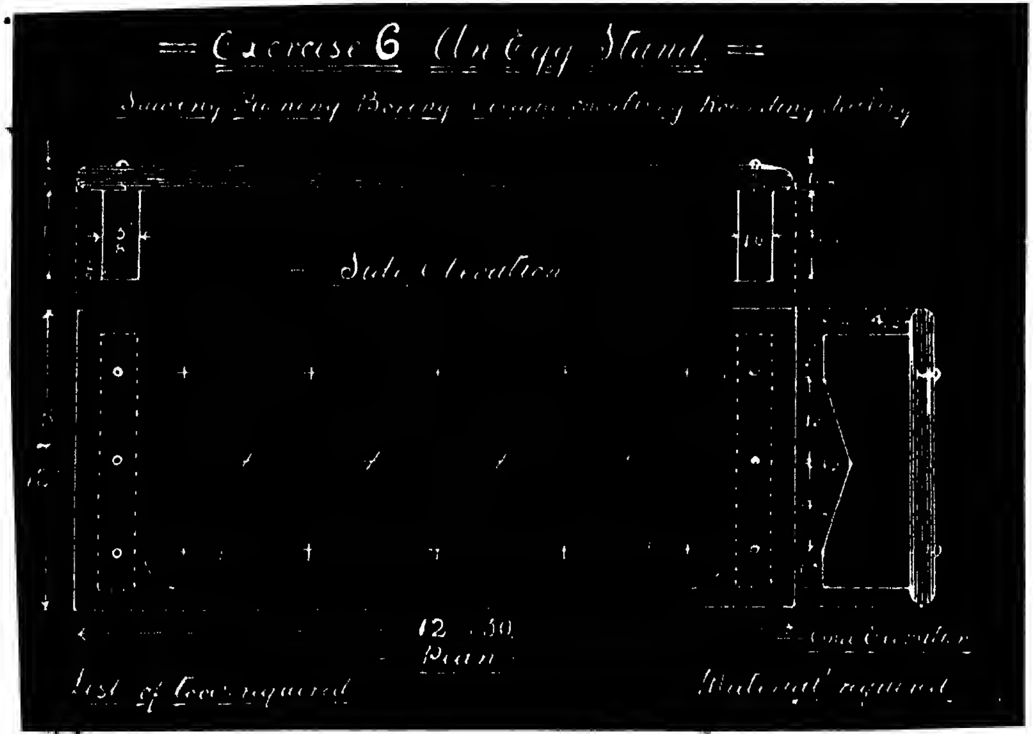
NOTE.—These points should be dealt with during the drawing lessons and reviewed in subsequent lessons.

Remarks on Tools.—Question during demonstrations concerning methods of holding the various tools and the names of various parts.

The File.—Call attention to manner in which teeth are formed. Explain abrading action of files.

Glasspaper.—Call attention to general structure. Necessity for all particles to be of uniform size. Demonstrate effect of having just one particle of glass larger than remainder, i.e. a scratch wherever it comes in contact with the work.

Timber.—Review comparison between clear pine, red pine, and poplar. Take small waste pieces of each, and, splitting each, demonstrate straightness of grain. Exhibit planks and call attention to freedom from knots. Examine end grain and call attention to markings, i.e. annual rings. Compare specimens for visibility of annual rings. Take specimens of equal volume and compare weights—approximate test. Later, the specimen should be tested on balance. Demonstrate approximate of relative hardness by delivering uniform blows with a hammer on specimen pieces of each. Point out countries on map whence supplies are obtained.


Exercise 6 An Egg Stand
Side Elevation
Plan
End Elevation
List of Tools required
Material required

EXERCISE VI

AN EGGSTAND

Exercises Involved.—Marking out and sawing from plank. *Planing broad surfaces.* Planing to dimensions. Marking out. Boring large holes. *Sawing long cuts with tenon saw. Planing to semi-cylindrical form in direction of grain and across the grain. Oblique stopped chiselling.* Chamfering with the chisel across the grain. *Nailing together of various parts.*

Instructions.—Allow the scholars to examine the teaching model and measure its various parts, and from the data so obtained prepare a plan, side elevation, and end elevation. It will be seen that the end elevation is necessary in order to show the true shape of the bearer.

Fig. 256

NOTE.—In order to draw the semicircular ends in the elevations, proceed as shown in accompanying sketch (fig. 256) by making A B equal to A D, i.e. the thickness of the top. At B erect a perpendicular B C, thus completing the square A B C D. Draw the diagonals, and through the centre G draw E F perpendicular to A B. With G as centre and radius G E draw the semicircle E H F.

NOTE.—*Unless carefully watched scholars are apt to be careless in the execution of this portion of the work.*

Question the class concerning the processes involved in the making of the model, the tools required, and material that would prove serviceable, and complete the list of tools and material.

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Try square. Gauge. Marking knife. Tenon saw. Brace and 1¼-in. centre bit. ¾- or 1-in. firmer chisel. Bradawl. Smoothing plane. Glasspaper. Hammer.

Material Required.—One piece of clear pine, poplar, or satin walnut, 13 in. by 5½ in. by ½ in.; one piece of clear pine, poplar, or satin walnut, 11 in. by 2 in. by ¾ in.; six 1-in. brass escutcheon pins.

Benchwork.—STAGES.—

1. Mark out plank and saw out material.
2. Plane material to dimensions.

NOTE.—See that each stage is carefully performed in its right order, as previously detailed.

3. Mark off length of top, and set out the centres of the holes, i.e. it is not necessary to draw the circles; the centre bit will make its own circles. Mark out bearers; they should not be separated until the notches on the under sides have been chiselled.

4. Saw off the waste at the ends of the top piece, sawing to the line, and proceed to round the edges in the following manner.

Make a thumb gauge having a notch $\frac{3}{16}$ in. long, and mark pencil lines round both surfaces and along the middle of the edges and ends. These lines on the faces show where the rounding ceases and the line on the edge indicates the crown of the curve. Having made these marks, proceed to round the ends first. This is done with the smoothing plane, the plane being held obliquely after the manner in which the chisel was held for chamfering across the grain. Having completed the ends, proceed to round the long edges, using the jack plane or smoothing plane as in the case of the round ruler.

5. Bore the holes in the top.
6. Chisel the notches on under side of bearers.

(See note on this in Chapter on "Chiselling Processes".)

7. Cut off bearers to length and chamfer the ends.
8. Clean off surfaces with smoothing plane, and glasspaper the curved edges and ends of the top piece.
9. Mark on the under surface of the top the position of the bearers. Bore the nail holes. Nail top to bearers.
10. Compare finished work with the drawing.

Demonstrations.—

1. Marking out the plank, sawing, and planing. The extra difficulty of planing a broad surface should be carefully explained.
2. Marking out of top and bearers.
3. Sawing off waste and method of guiding the tenon saw across a broad surface.

NOTE.—There is a tendency among scholars, when making long cuts with the tenon saw, to rest all the teeth of the saw upon the wood at starting, with the result that when the saw is pushed forward it slips away from the

line, thus producing a ragged cut, and damage to the surface of the exercise. The principle of starting with the tip of the saw at the far end of the line, and gradually lowering the blade at each successive stroke, the blade being guided to the line by means of the left thumb, should be rigidly adhered to. This exercise correctly performed develops the confidence of the pupil.

4. Marking and rounding of ends and edges.

Draw attention to the ease with which the corners are split when planing the ends, if the axis of the plane be held in line with the edge of the model. Refer to similar action when chamfering the end of the first portion of Exercise II.

5. Boring holes.

NOTE.—Demonstration is not really necessary, but the lesson affords an opportunity of questioning concerning the principles taught in previous lessons.

6. Method of chiselling the notches and finishing bearers.

NOTE.—Draw attention to the necessity for exercising perfect control over the chisel when making the finishing cuts, in order that the two planes shall meet in an edge.

7. Glasspapering the curved edges.

(a) *The Ends.*—The work is fixed in the vice and a strip of glasspaper stretched over the end. The ends of the glasspaper are firmly grasped between the thumb and first finger of each hand and held close in to the faces of the work. The hands are then alternately raised and lowered, at the same time being moved forward and backward in line with the axis of the cylindrical surface to be produced. In this way the whole of the curved surface is brought under the action of the glasspaper and a good curve produced.

(b) *The Edges.*—These can be treated in a similar manner, but should be finished by imparting a forward-and-backward motion only to the glasspaper.

8. Nailing together of parts and testing finished work.

Lessons on Tools.—Question the class concerning the names of the various parts of the jack plane. It will be necessary to tell the scholars the names of such parts as cannot be named after examination. Explain the use of the button, and reason for iron becoming loose when the button is struck. Method of taking irons apart for sharpening and resetting.

Timber.—Should satin walnut have been used for this exercise, make a comparison between this and other woods previously used.

Calculations.—What will be the length of a cylinder having a diameter

equal to the diameter of the holes bored, which shall represent the amount of wood removed when boring the holes?

How many holes are there? How deep is each hole? Then—

$$14 \text{ in.} \times \tfrac{3}{8} \text{ in.} = \tfrac{42}{8} = 5\tfrac{1}{4} \text{ in.}$$

The method of finding the volume could be explained to an advanced class thus:

Area of circle = diameter multiplied by diameter or $(d^2) \times \cdot 7854$.

Volume of a cylinder = area of end multiplied by length of axis.

SUMS.—1. There are twenty boys in the class. Each boy bores fourteen holes $1\frac{1}{4}$ in. diameter and $\frac{3}{8}$ in. deep. How much material is consumed in the process?

2. How many square inches of surface will have been removed during the process of boring the fourteen $1\frac{1}{4}$-in. holes?

EXERCISE VII

A RECTANGULAR BOX

Exercises Involved.—Marking out and sawing from the plank. Planing (longer piece). Marking out. Sawing with tenon saw. *Grooving for housing joint.* Vertical chiselling. End-grain planing. *Nailing together of parts.* Cleaning off work with smoothing plane.

Instructions.—Allow scholars to examine the teaching model and measure all its parts. Explain the principle of the *housing joint* involved and the advantages of such a joint compared with simply nailing in the ends flush with the end of the sides.

Prepare a plan, side elevation, and end elevation.

Carry the explanation of the principles of orthographic projection a stage further.

Exhibit model of dihedral angle and show the position of the model as related to the planes of projection in order to afford the views to be drawn.

Explain the necessity for having dotted lines marking the position of the grooves in elevation, and why such lines are dotted.

Question the class concerning the various tools and material that will be required in order to make the exercise and write out the usual lists.

Tools Required.—Ruler. Pencil. Panel or cross-cut saw. Jack plane. Try square. Tenon saw. Gauge. Marking knife. Firmer chisels $\frac{1}{4}$ and $\frac{1}{2}$ in. Bradawl (fine). Hammer. *Nail punch.* Smoothing plane.

NOTES

Material Required.—One piece of clear pine or poplar, 18½ in. by 2¼ in. by ½ in.; one piece 7 in. by 3¼ in. by ½ in.; fourteen 1-in. oval wire nails.

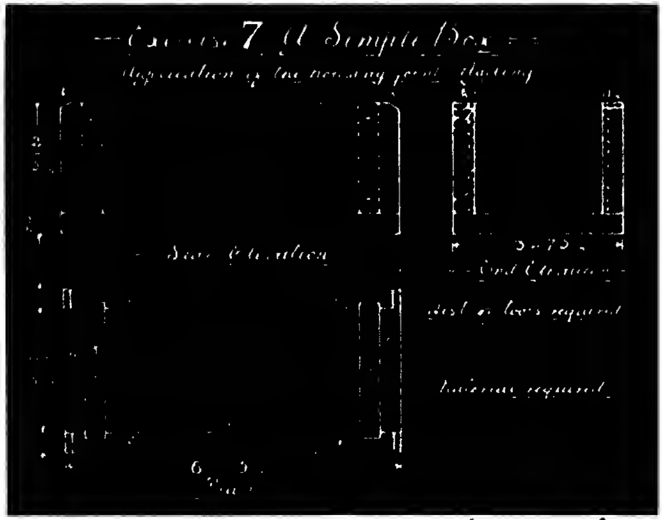


Fig. 257

Benchwork.—STAGES.—

1. Mark out plank and saw out material.
2. Plane material for sides and end. This should be kept in one length until planed, marked out, and grooves cut.

NOTE.—There is a tendency among scholars to cut their work into small pieces and then to execute any necessary work on such short or small pieces. This principle is bad, and should never be allowed. There is always more danger of a scholar injuring himself when working on such small pieces. There is less scope for the performance of satisfactory work. Numerous small pieces are apt to be mislaid or lost.

Make it a standing rule that the material is not to be separated into parts until all possible work has been executed on such pieces in the bulk.

3. Mark out work.
4. Saw and chisel grooves.
5. Saw off various parts.

(a) End pieces should be cut to the line.

(b) Side pieces should be cut $\frac{1}{16}$ in. from the line to allow for planing (shooting) the ends

6. Clean off inner surfaces of sides and both surfaces of end pieces, and nail sides and ends together.

7. Plane piece for bottom of box; this should be kept slightly wider than is actually required.

8. Mark off length of bottom. Saw off waste $\frac{1}{16}$ in. away from the line. Mark position of nail holes. Clean off inner surface. Nail bottom to framing.

NOTE.—Scholars must be warned to keep the top framing square whilst nailing on the bottom. This can be accomplished by first nailing along one side, then testing work with the try square and holding the parts firmly whilst a nail is inserted a short distance on the other side, then testing again, making any necessary corrections before driving home the nail.

9. Punch all nails below the surface, and clean off all outer surfaces.

NOTE.—Explain the effects of not punching the nails to a sufficient depth. It will be found that scholars, in their eagerness, often really do not observe that they are planing the head of a steel nail, and have no knowledge of its disastrous effects on the surface of the plane and the cutting iron.

Remember that knowledge is only an accumulation of experiences.

10. Plane the ends of the box to the line.

Special care is here required in the manipulation of the smoothing plane.

11. Compare finished work with drawing.

Demonstrations.—

1. Marking out the plank, sawing, and planing.
2. Marking out, sawing, and chiselling grooves.
3. Sawing off waste. Smoothing various parts and nailing together.

NOTE.—Question the class concerning the advantage of inclining the nails.

4. Nailing on bottom and planing off outer surfaces of model.
5. Method of planing off the end grain at ends of box.

NOTE.—The plane must be held on the skew, and the successive strokes taken inwards, in order to avoid splitting at the outer ends.

NOTES

Lessons.—Explain the "housing joints". Question the class concerning other examples of the use of such a joint.

Tools.—Simple questions concerning the various tools that have been used during the exercise.

Deal more in detail with the tenon saw, and make a comparison with the panel saw.

Tenon Saw	Panel Saw.
Handle open.	Handle closed.
Blade rectangular.	Blade tapering.
Blade thin.	Blade fairly thick.
Teeth small, 14 per inch.	Teeth much larger, 8 per inch.
Brass stiffening rib.	No stiffening rib.
Chiefly used in horizontal position.	Chiefly in an oblique position.
Amount of set, small.	Amount of set, greater.
Makes a fine kerf.	Kerf much coarser.
Only used for shallow cuts.	Used for deep cuts.

Timber.—Name of wood used. Nature and properties. Uses to which applied. Used by patternmakers; reason for this. Compare holding power of nails and glue when used in connection with the wood.

Calculations.—

What is the area of the bottom of the box outside?
What is the area of the bottom inside?
What is the area of one of the long sides outside?
What is the area of the long sides inside?
What is the area of the ends?
What is the capacity of the box?

$$(4\tfrac{1}{2}\text{ in.} \times 2\tfrac{1}{4}\text{ in.} \times 2 = 20\tfrac{1}{4}\text{ cu. in.}).$$

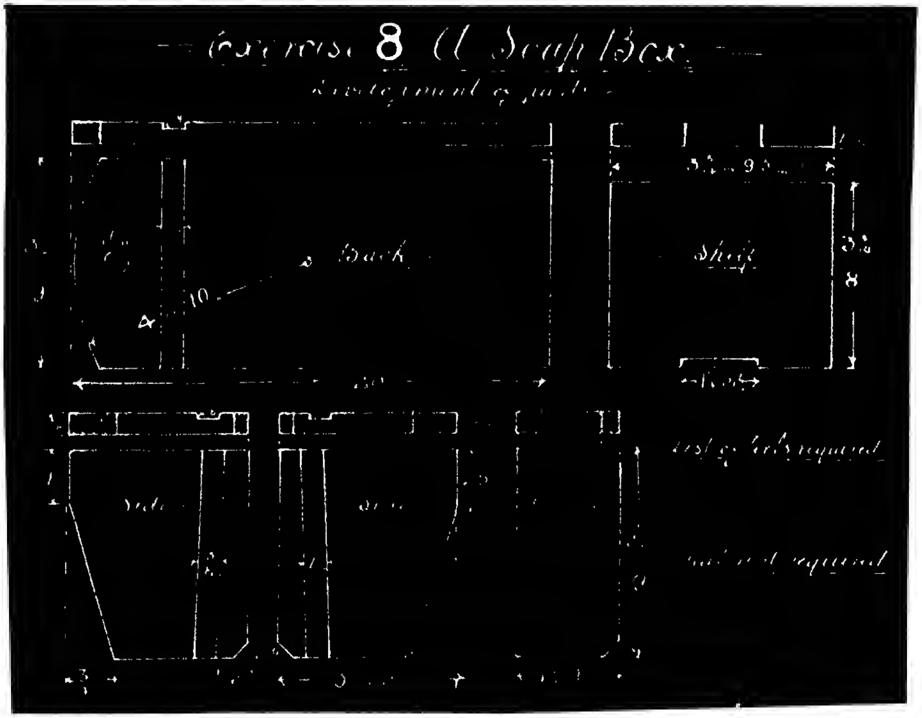
How many cubic inches of wood have been used in making the box?

Sides,	$6\text{ in.} \times 2\text{ in.} \times \tfrac{3}{8}\text{ in.} \times 2$	$= 9$ cu. in.
Ends,	$2\tfrac{1}{2}\text{ in.} \times 2\text{ in.} \times \tfrac{3}{8}\text{ in.} \times 2$	$= 3\tfrac{3}{4}$ cu. in.
Bottom,	$6\text{ in.} \times 3\text{ in.} \times \tfrac{3}{8}\text{ in.}$	$= 6\tfrac{3}{4}$ cu. in.
		$19\tfrac{1}{2}$ cu. in.

Assuming that there are x[1] nails to the pound, determine the number of boxes for making which $\tfrac{1}{2}$ lb. of nails will suffice?

How would you calculate the number of nails per pound?

[1] Set a scholar to count the number of nails, in, say, 1 oz., or if scales are not available, then count the number of nails in a packet the weight of which is known, and determine the number per pound from the data obtained.


Exercise 8 A Soap Box.
Back
Shelf
10
8

EXERCISE VIII

A SOAP BOX

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. More difficult example in marking out. Sawing with tenon saw. Grooving for housing joints. *Sawing convex curve with bow saw. Spokeshaving convex curve.* Boring. End-grain shooting. *Shooting obliquely across the grain.* Vertical chiselling (*a*) in the direction of the grain, (*b*) across the grain. More difficult example in nailing. *Using screws.*

Instructions.—Allow the scholars to examine the teaching model and measure all its parts, noting carefully the direction of the grain of the wood in each part, and proceed to draw a development of all the parts as shown in accompanying fig. 258.

Fig 259

Note.—It is advisable that a development be drawn in this case, owing to the apparent complications of the parts. Care should be taken to explain the necessity for "pairing" the side pieces, i.e. setting them out opposite-handed, as shown in drawing. The development shows clearly how the various parts will be marked out on the wood, with respect to the direction of the grain of the wood.

The back, shelf, and sides are prepared in one piece. The top shelf can be prepared from a small odd piece. The curved top presents an opportunity for explaining the following problem:—

Find the centre of a circle, having given an arc of the circle.

Proceed as follows: Lay the teaching model on a piece of paper, and mark round the curved top with a pencil, as AB in fig. 259. Take any point C in the curve, and join AC, BC, chords of the required circle. Bisect AC, BC, and produce the bisectors to intersect in D, which will be the centre of the circle.

Chord.—Any straight line, having its extremities in the circumference of a circle.

Arc.—Any portion of the circumference of a circle.

Bisect.—To cut into *two* equal parts.

Question the class concerning the tools and material required, and write lists of such tools and material.

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Try square. Gauge. Marking knife. Compass. Tenon saw. Firmer chisels, ¼ and ¾ in. *Bow saw. Spokeshave (iron).* Brace and ⅜-in. centre bit. Bradawl (fine). Smoothing plane. Hammer. Nail punch (small). Screwdriver (small).

Material Required.—One piece of clear pine, poplar, or satin walnut, 19 in. by 3¾ in. by ½ in.; one piece, 4 in. by 2 in. by ½ in.; eight 1-in. oval wire nails; two ¾-in. No. 6 screws.

Benchwork.—STAGES.—

1. Mark out plank; saw and plane material to dimensions.
2. Mark out work as shown in drawing.
3. Saw and chisel grooves.
4. Saw and chisel notch in shelf.
5. Bore the hole.
6. Saw and spokeshave curved top
7. Saw off the various parts, cutting about $\frac{1}{32}$ in. from the line to allow for shooting exposed ends.

NOTE.—Ends not exposed, as in the case of the shelf, should be sawn off direct to the line.

8. Vertically chisel the corners where so marked.
9. Shoot all exposed ends, i.e. plane on shooting board.

NOTE.—The necessity for chiselling the corners and then so arranging the material on the shooting board that the plane advances towards the chiselled corner should be explained.

Ask the scholars what would happen were this not attended to.

10. Bore the nail and screw holes. Smooth the surfaces and fit various parts.
11. Nail the sides to the back. Fit and nail the bottom shelf in position. Fit and screw the top shelf in position. Remove the waste at the front edge of the bottom shelf with the plane.
12. Compare finished work with the drawing.

Demonstrations.—

1. Mark out the work, explaining carefully the necessity for reversing the side pieces, i.e. pairing.

2. Bow-sawing and spokeshaving top curve.

3. Shooting exposed ends.

4. Nailing and screwing together of various parts.

Lessons: Tools.—Deal with various tools used during the exercise. Name the parts of the bow saw, and question concerning the purpose served by such parts. Explain briefly the advantage of a spokeshave.

Timber.—Deal briefly with the first principles of growth. Parts of a tree. Ascent of sap. Heartwood. Sapwood. (Exhibit samples.)

Calculations.—What is the area of each of the parts, neglecting the corners which have been removed?

NOTE.—An advanced class could take the corners into account.

What is the volume of the various parts?

What is the approximate weight of the model? (Neglect holes, corners, grooves, and assume that 1 cu. in. of the wood used weighs $\frac{1}{2}$ oz.

How many of these models could be made from a plank of wood 10 ft. by 12 in. by $\frac{1}{2}$ in.?

EXERCISE IX

A TOILET BOX

Exercises Involved.—Marking out and sawing from the plank. Planing to dimension. More difficult examples in marking out, involving geometrical construction. Sawing with tenon saw. Grooving for housing joint. Sawing convex curves with bow saw. Spokeshaving convex surfaces—more difficult examples. *Ornamental boring.* End-grain shooting. Chamfering with and across the grain. Using smoothing plane. Fitting and nailing. *Ornamental nailing*, i.e. brass escutcheon pins should be used for nailing the front.

Instructions.—Allow the scholars to examine the teaching model and measure all its parts.

Prepare a development of such parts, as shown in accompanying fig. 260.

NOTE.—Construction at top of back. Method of describing an equilateral triangle. Method of constructing a "Trefoil".

Question the class concerning the various tools to be used and material required, and write out the lists of such tools and material.

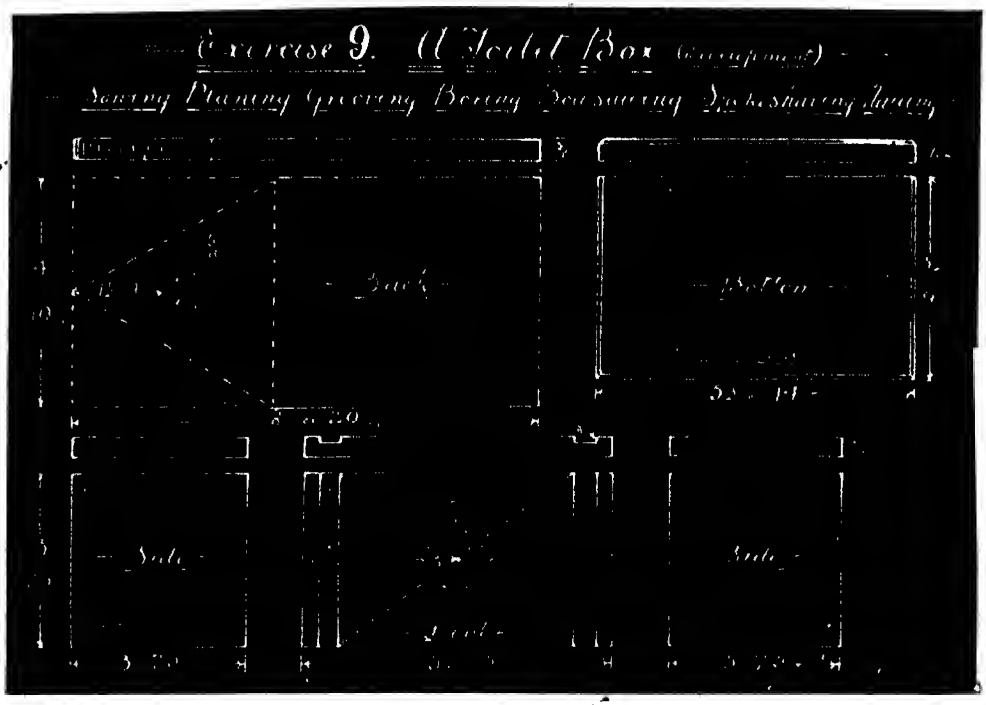


Fig. 280

NOTES

Tools Required.—Ruler. Pencil. Panel or crosscut saw. Jack plane. Try square. Gauge. Marking knife. Tenon saw. Firmer chisels, ¼ and ½ in. Bow saw. Spokeshave (iron). Brace and centre bits, ½, ⅝, and 1 in. Bradawl (fine). Smoothing plane. Hammer. Nail punch.

Material Required.—Satin walnut answers well for this model. Other fancy woods may be used, provided they be not too hard for the particular scholars about to make the exercise.

NOTE.—The back and bottom is made from one piece, the sides and front being made from another piece.

For the back and bottom, one piece 14½ in. by 4¼ in. by ½ in.; for the front and sides, one piece 12 in. by 3¼ in. by ½ in.; ten 1-in. oval wire nails; four 1-in. brass escutcheon pins.

Benchwork.—STAGES.—

1. Mark out, saw, and plane material to dimensions.

NOTE.—The piece for the bottom is kept the full width of the back until ready for nailing in position. It will be seen that by so doing the danger of spoiling the corners when chamfering is thus avoided.

2. Mark out all work, as shown in drawing.
3. Saw and chisel grooves.
4. Saw and spokeshave curved top.

NOTE.—Scholars usually make two mistakes when performing this exercise:

(*a*) The spokeshave is allowed to "dip" into the material at starting, thus making a "hollow place" where the tangent edge meets the curved edge.

(*b*) In rolling the spokeshave over the curved edge too much is taken off at the point, thus forming a blunt intersection, which looks unsightly.

The exercise is purposely intended to afford opportunity for developing command of wrist manipulation.

5. Separate the parts, sawing away from line when the ends are exposed, and to the line for ends not exposed. Plane (shoot) exposed ends. Chamfer base. Clean off surfaces ready for nailing together.
6. Nail the front and sides together.

NOTE.—The side pieces being "square", scholars often arrange these with grain running the wrong way. Explain this point, and question concerning the reason for having the end grain buried in the groove.

Nail the sides to the edge of the back.

Nail the bottom in position.

(See note on "Rectangular Box", concerning the squaring of parts, before driving all nails in position, page 265.)

7. Compare finished work with drawing.

Demonstrations.—

1. Marking out the work. Sawing and spokeshaving the curves at the top.

NOTE.—Call attention to the probable errors, as already mentioned, and show how these are to be avoided.

2. Boring the holes.

NOTE.—There is a tendency among scholars to bore the centre hole first. Demonstrate this on a spare piece, questioning meanwhile concerning advantages or disadvantages.

3. Nailing the parts together. Special care is needed when nailing on the bottom.

Lessons: Tools.—Deal more fully with the brace and its various parts. Leverage obtained by means of crank. Compare amount of leverage in following tools: Bradawl, gimlet, brace. Compare cutting action of bradawls, gimlets, and centre bits.

Timber.—Review remarks on satin walnut. Examine transverse section of tree. Note and name parts seen. Explain briefly absence of distinct annual rings in tropical and subtropical trees.

Calculations.—Find the area of the various parts, neglecting curves and holes.

Find the area of the back, taking the top curve into consideration, using $\frac{1}{8}$-in.-squared paper for the purpose.

Find the cubic capacity of the box portion inside.

(4 in. × $2\frac{1}{2}$ in. × 3 in. = 30 cu. in.)

How many 1-in. brass escutcheon pins are contained in 1 lb.?

What would be the length of the wire, assuming that 1 lb. of 1-in. nails were placed end to end?

How many boys can be supplied with nails for this box from a packet containing $\frac{1}{2}$ lb. of nails?

EXERCISE X

A HALF-LAPPED JOINT

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Marking out. Sawing. Chiselling a broad surface. Accurate fitting

Instructions.—DRAWING.—This exercise affords an excellent opportunity for introducing isometric projection. Briefly explain the advantages and principles as set forth in the chapter on "Principles of Projection".

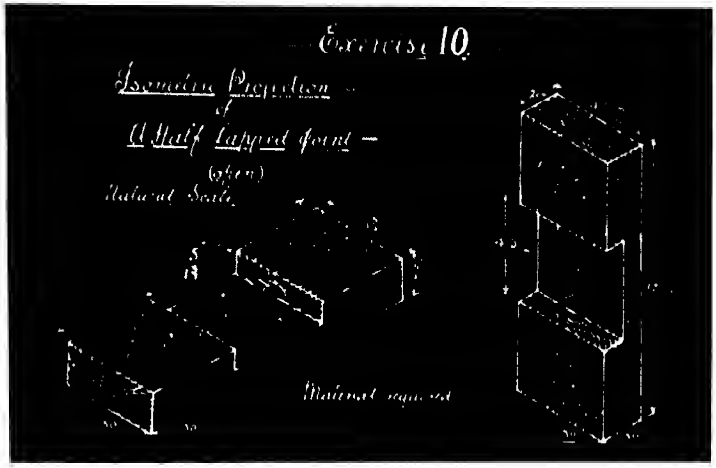


Fig. 261

Prepare an isometric view of each part as shown. Question concerning the tools and material required, and write out the usual lists.

Tools.—Ruler. Pencil. Panel saw. Jack plane. Try square. Gauge. Marking knife. Firmer chisel, ¾ or ½ in. Smoothing plane.

Material Required.—One piece of pine or poplar, 12 in. by 2 in. by 1 in.

Benchwork.—STAGES.—

1. Mark and saw out material.
2. Plane material to dimensions.
3. Set out grooves.

NOTE.—Explain necessity for the grooves being reversed on each piece, i.e. on the face side of one and back of the other; also necessity for gauging the grooves from the *face side* in each case.

4. Saw and chisel grooves.

NOTE.—In such cases where wide grooves have to be chiselled, one or more extra cuts can be made across the waste. Such cuts should not extend quite to the gauge mark. (See Part II, Chapter VI, "Chiselling Processes".)

5. Separate the parts and fit together. Clean off surface with smoothing plane.

This exercise affords an excellent opportunity of bringing home to the scholars the importance of accurate work in all details. They must saw confidently to the lines. The joint either fits or it does not fit. *No* patching or faking should be allowed. Accurate self-reliant work on the part of the scholars is the main aim; not merely two pieces of wood fitting tightly together.

Demonstration.—Make the joint from the start to finish, and let the scholars see how quickly such an exercise can be made, and the nature of the work produced by careful, accurate, self-reliant effort.

The cleaning off should be carefully explained. The grain of the wood crossing at right angles presents a new difficulty. The plane must be held on the skew, and it should not be allowed to dip when approaching the ends of the respective pieces.

NOTE.—Scholars are very apt to make the ends of each piece thin.

Lessons.—TOOLS.—Deal more fully with the parts of the firmer chisel. Question briefly concerning other tools used during the lesson.

Timber.—Carry previous lesson on transverse section a stage farther.

Calculations.—

Areas of surfaces of each piece.
Volume of each piece before making the groove.
Volume of waste removed from each groove.
Volume of complete model.

NOTES

$$10\text{ in.} \times 1\tfrac{3}{4}\text{ in.} \times \tfrac{3}{4}\text{ in.} - 1\tfrac{3}{4}\text{ in.} \times 1\tfrac{3}{4}\text{ in.} \times \tfrac{3}{4}\text{ in.}$$
$$= 8\tfrac{1}{4}\text{ in.} \times 1\tfrac{3}{4}\text{ in.} \times \tfrac{3}{4}\text{ in.} = \tfrac{33}{4}\text{ in.} \times \tfrac{7}{4}\text{ in.} \times \tfrac{3}{4}\text{ in.}$$
$$= \frac{693}{64}\text{ in.} = 10\tfrac{53}{64}\text{ cu. in.}$$

When twenty boys make this exercise, determine the volume of wood wasted in making the grooves.

$$1\tfrac{3}{4}\text{ in.} \times 1\tfrac{3}{4}\text{ in.} \times \tfrac{3}{8}\text{ in.} \times 2\text{ in.} \times 20\text{ in.} = \frac{5880}{128} = 45\tfrac{15}{16}\text{ cu. in.}$$

There are twenty boys in the class; each boy is given a piece of wood 12 in. × 2 in. × 1 in. from which to make the model. Find the exact amount of wood wasted, assuming the volume of finished model to be 11 cu. in.

Volume of piece given to each scholar.

$$12\text{ in.} \times 2\text{ in.} \times 1\text{ in.} = 24\text{ cu. in.}$$

Volume of the model 11 cu. in.

Then $(24 - 11) \times 20 = 13 \times 20 = 260$ cu. in.

EXERCISE XI

A STRING WINDER

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions (long piece). Marking out—pairing pieces. Cross-grain sawing. Chiselling—grooves and chamfers. Accurate fitting of parts. Use of screws. More difficult example in cleaning off.

Instructions.—DRAWING.—Prepare a plan, part elevation, and section, as shown. Explain the use of sections and how projected. An isometric view of one corner may be prepared, applying the principles taught in the previous lesson. Question concerning tools and material required, and complete the usual lists.

Tools.—Ruler. Pencil. Panel saw. Jack plane. Try square. Gauge. Marking knife. Tenon saw. Firmer chisel, ¾ in. Bradawl. Small screwdriver. Smoothing plane.

Material Required.—One piece of pine or poplar 32 in. by 1¾ in. by ⅞ in.; four ½-in. No. 4 screws.

Benchwork.—STAGES.—

1. Saw out and plane material to dimensions.

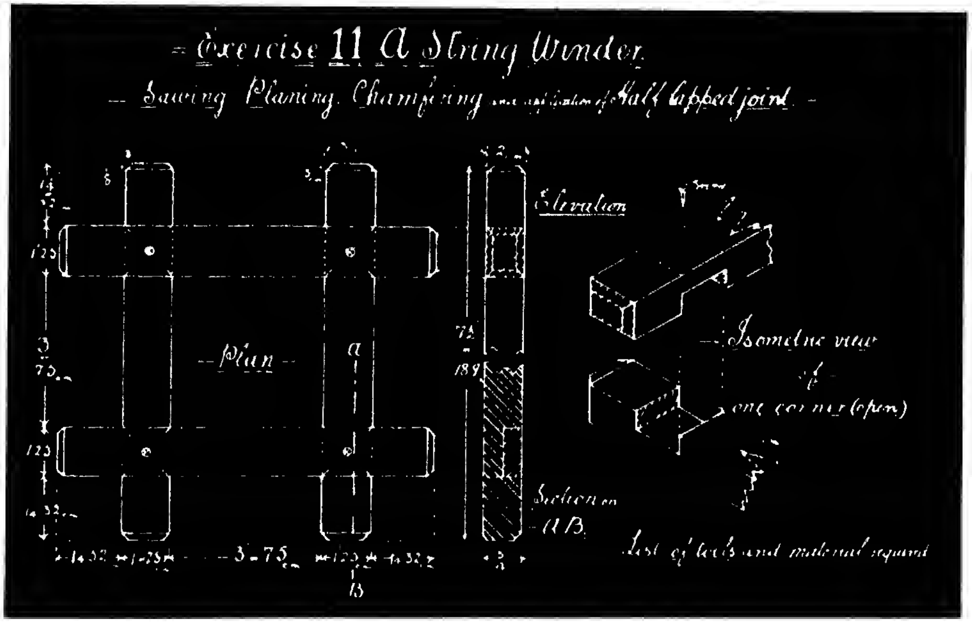

Exercise 11 A String Winder
Sawing Planing. Chamfering and application of Half lapped joint.
Elevation
Plan
Isometric view of one corner (open)
Section on AB.
List of tools and material required

Fig. 262

2. Mark out grooves as shown in fig. 263. Explain the necessity for adopting this method, i.e. it ensures that opposite sides of the rectangle are equal in length. (*a*) Two pieces marked on face side; (*b*) Two pieces marked on back. (See last lesson.)

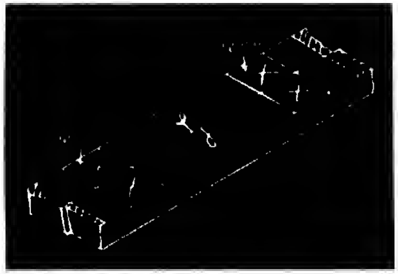


Fig. 263

3. Saw and chisel the grooves.

4. Cut each piece to length and chamfer the ends.

5. Fit parts. Screw together and clean off.

NOTE.—Call attention to necessity for all screw heads being turned well below the surface.

Question concerning method of holding plane for cleaning off surfaces where the grain in the several parts crosses at right angles.

Demonstrations.—

1. Method of marking out the grooves.
2. Screwing together and cleaning off.

Lessons: Tools.—The screwdriver. Parts. Advantage gained through having pear-shaped handle.

Material.—Compare screws with nails for holding power. (See lesson on "Screws".)

Timber.—General questions concerning timber used and geographical distribution.

Calculations.—

1. How many cubic inches of wood will each boy require for the exercise?
2. What is the volume of the complete model, neglecting chamfers?
3. How much planking 12 in. wide will be required for a class of eighteen boys in order that each may make this model (allow $\frac{1}{8}$ in. for saw kerfs)?
4. What will be the internal dimensions of a box sufficiently large to hold the eighteen models for export?
5. Assuming the box to be made of $\frac{1}{2}$-in. material throughout, calculate the weight of box and models packed ready for export.

Experiment.—Weigh a piece of the material to be used, and calculate the weight per cubic foot in order to solve the previous problem.

6. What will it cost to send the parcel from A to B per Parcel Post, the rate being x*d.* per pound?

EXERCISE XII

A WALL BRACKET

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Marking out including more complicated curves. *Stopped grooving. Bow sawing—concave and convex curves.* More difficult exercise with spokeshave. *Vertical chiselling of stopped curved surfaces.* More difficult examples in cleaning off, use of nails, use of screws.

Instructions.—DRAWING.—Prepare a development as shown. Explain tangent curves. Quadrants. Prepare an isometric projection of one of the parts, explain method of construction for drawing quadrants. (See chapter on "Principles of Projection".)

NOTE.—The isometric projection of the support is somewhat difficult for beginners, but with careful attention to detail may be mastered.

Question concerning tool processes, material required, and complete the usual lists.

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Try square. Gauge. Marking knife. Compass. Firmer chisels (various). Tenon saw. Bow saw. Spokeshave (small wooden). Brace and $\frac{1}{4}$-in. centre bit or Forstner bit. Bradawl. *Small pin bit. Countersink.* Smoothing plane. Cork rubber. Hammer. Screwdriver (small).

Material Required.—Poplar. Cedar. Satin walnut. Black walnut may be used for this model. The selection must depend upon the strength of the individual scholars. Black walnut looks well but is more difficult for scholars to work than the foregoing examples.

One piece 14 in. by $4\frac{3}{4}$ in. by $\frac{1}{2}$ in.; one piece 8 in. by $2\frac{1}{4}$ in. by $\frac{1}{2}$ in.; nails, three 1-in. oval wire nails or finishing pins; screws, two $\frac{3}{4}$-in. No. 4; glue; glasspaper (fine).

Benchwork.—STAGES.—

1. Prepare all material.
2. Mark out as shown in development.
3. Make stopped groove.

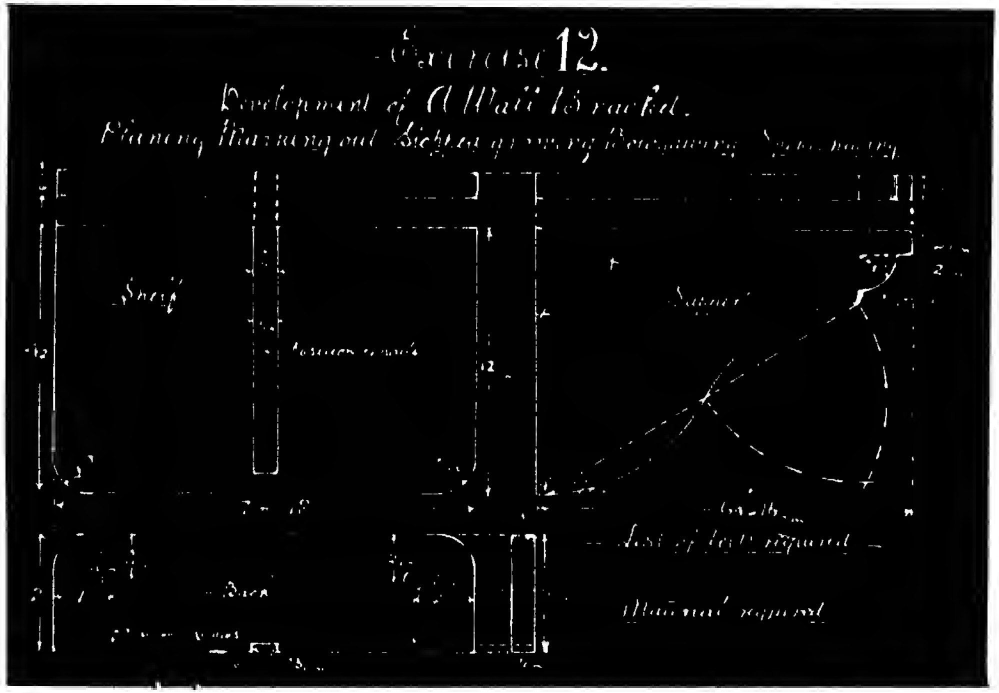

Exercise 12.
Development of A Wall Bracket.
Shelf
Support
List of bolts required
Material required

Fig. 264

NOTES

4. Saw and spokeshave large curves.
5. Chisel quadrant at bottom of support.
6. Separate parts, round off the corners of shelf, and shoot the ends.
7. Round off the corners of back and bore holes.
8. Clean all parts. Glue and nail shelf to support. Screw the back to the shelf.

Demonstrations.—

1. Marking out the curves.
2. Method of forming stopped grooves. (See chapter on "Chiselling".)
3. Sawing and spokeshaving curves, also chiselling quadrant at bottom of support.
4. Use of glasspaper.

NOTE.—The glasspaper should be rubbed only in the direction of the fibres. Show scratched appearance of work if papered across the fibres. Demonstrate the effect of papering across the fibres if the article is to be stained. (Ink will answer for a stain.)

5. Method of using glue and fixing model together.

Lessons: Tools.—Further lessons on bow saw and spokeshave. General questions concerning other tools used during the making of the model.

Timber.—Compare and contrast pine, poplar, satin walnut, black walnut.

Glue.—Nature of substance, preparation for use, necessity for water jacket.

Calculations.—

1. Find the area of the various parts.
2. Find the volume of the various parts.
3. Find the cost of the particular material used in making the model.
4. Find the cost of the screws used by the class at *x*d. per gross.
5. Find the volume of box required to contain one model.
6. Determine the best manner of packing the models together, and ascertain the dimensions of a suitable box large enough to hold all the models of a class according to the number of boys.

NOTES

COURSE II

EXERCISE I

A MORTISE-AND-TENON JOINT

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Marking out. Use of mortise gauge. Mortising. Tenon and shoulder cutting. Accurate fitting.

Instructions.—DRAWING.—Allow scholars to ascertain dimensions of parts—English or metric standard—and prepare an isometric projection of each part as shown.

Complete lists of tools and material.

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Try square. Gauge. Marking knife. *Mortise gauge. Mortise chisel.* Tenon saw. Smoothing plane.

Material Required.—One piece of red pine, white pine, or poplar, 13 in. by 2 in. by 1¼ in.

Benchwork.—STAGES.—

1. Prepare material.

NOTE.—*In all subsequent models of the course, all that pertains to the sawing out of material and preparation for marking out will be included in the first stage, as above.*

2. Mark off pieces and set out mortise and shoulder lines.

NOTE.—The shoulder lines should be finely cut with the marking knife. The position of the mortise should be marked with pencil.

3. Gauge the tenon and mortise. (See chapter on "Gauging" for method.)
4. Make the mortise.

NOTE.—In all "through" mortising the back edge should first be mortised,

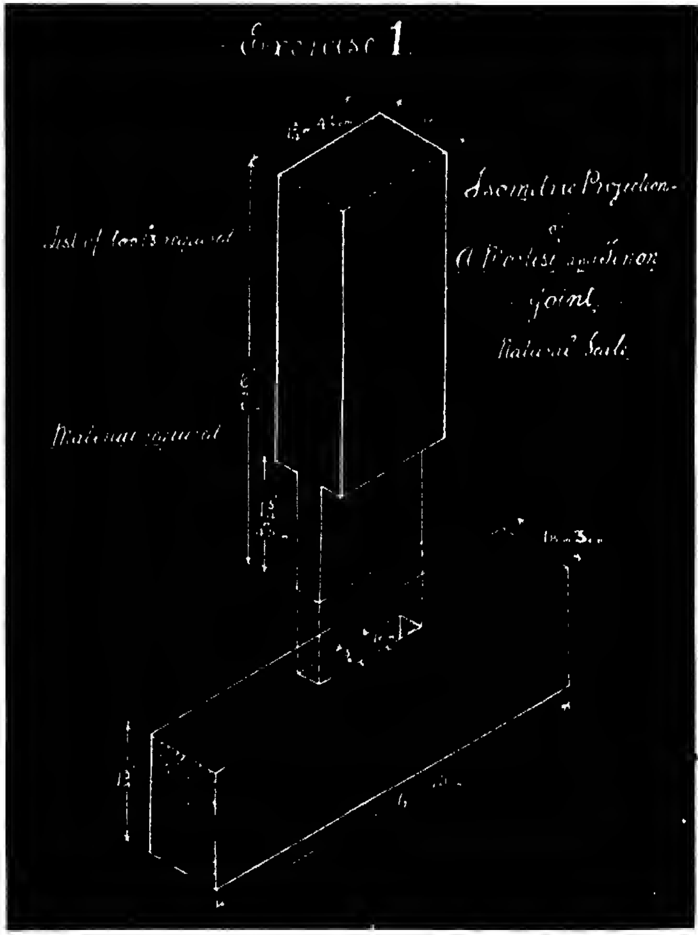

Exercise 1.
Isometric Projection
of
A Mortise and Tenon
joint.
Natural Scale

Fig. 265

the work is then turned over and the mortise completed from the face side or edge. The remaining core must be driven through from the face side.

5. Cut the tenon.

NOTE.—The cuts running in the direction of the grain must first be made, when these are completed the shoulders should be cut. Scholars often reverse this procedure with unsatisfactory results.

6. Separate the parts. Fit the parts together. Clean off.

Demonstrations.—

1. Marking out and using mortise gauge.
2. Mortising.
3. Sawing the tenon.
4. Fitting and cleaning off.

Lessons: Tools.—The mortise gauge. Compare with marking gauge.
The mortise chisel. Compare with firmer chisel.

Timber.—Growth of trees.

NOTE.—In the second year a more systematic course may be followed, dealing fully with the question of growth, felling, seasoning, geographical distribution, and method of importation. These can only be suggested in a limited form where each lesson is concerned. The teacher should map out his course at the beginning of each term and endeavour to carry out the work outlined for each class.

Calculations.—

1. Area of various surfaces.
2. Volume of hole.
3. Volume of material removed when making the tenon.
4. Volume of complete model.
5. Simple problems on application of forces.
6. Simple problems on the parallelogram of forces as applied to the gauge (see "Gauging").

NOTE.—During the second year the chapter on "Science" should be carefully explained and worked through, adopting in all cases very simple examples and accompanying the same by experiments whenever possible. Many very simple pieces of apparatus can be devised to demonstrate these experiments, but space will not permit their description here.

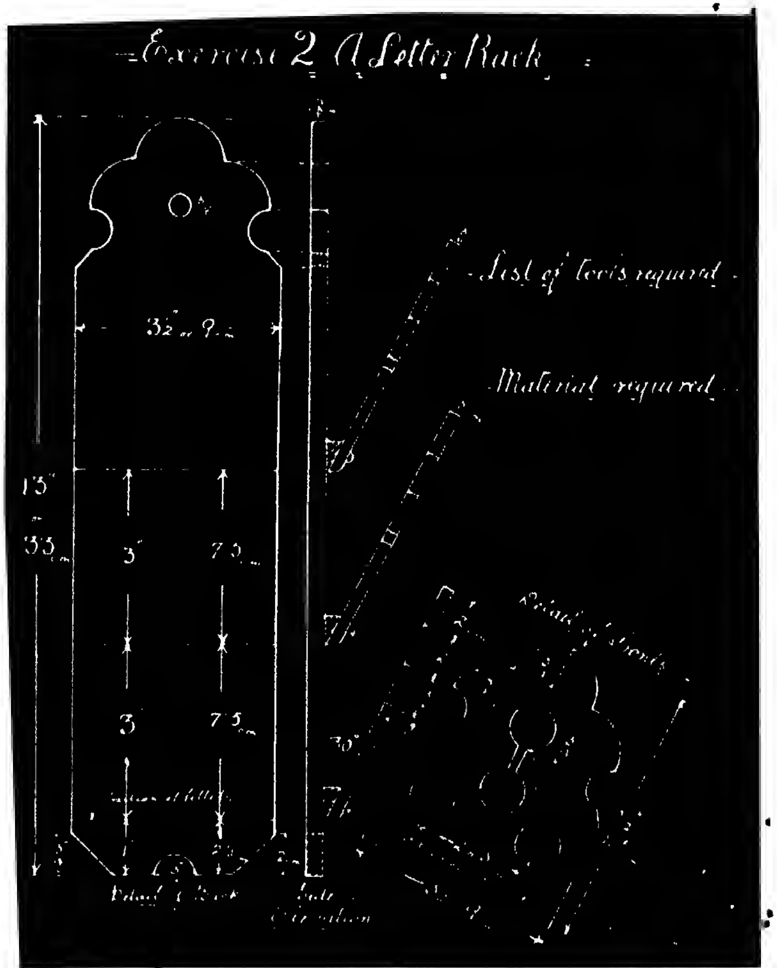

Exercise 2 A Letter Rack
List of tools required
Material required

Fig. 300

EXERCISE II

A LETTER RACK

Exercises Involved.—Sawing and planing in hard wood. More difficult example of marking out. Vertical chiselling of flat and curved surfaces in hard wood. Boring. *Gluing.* Nailing. *Use of brass round-headed screws. Splayed work.*

Instructions.—Drawing.—Prepare the views shown. Explain the principle of change of ground line and method of projecting the front. Prepare list of tools and material.

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Try square. Gauge. Marking knife. Compass. Brace and Forstner bits (various). Tenon saw. Firmer chisel. *Bevel.* Bradawl. Smoothing plane. Hammer. Small screwdriver.

Material Required.—Selected hard woods. This model looks well with a dark back piece and light fronts, such as black walnut and sycamore. Back and fillets, one piece 14 in. by $4\frac{1}{2}$ in. by $\frac{7}{16}$ in.; fronts, one piece $14\frac{1}{2}$ in. by $3\frac{3}{8}$ in. by $\frac{1}{4}$ in.; nails, six $\frac{1}{2}$-in. oval wire or finishing pins; screws, six $\frac{3}{8}$-in. No. 4 brass round heads.

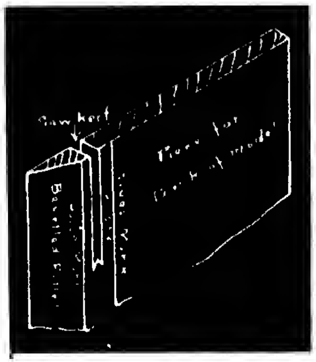


Fig. 267

Benchwork.—Stages.—

1. Prepare material.

Note.—The piece for the back and fillets is prepared in one piece. The piece for the fillets is gauged to width along one edge and bevelled, after which it is sawn off, and the cut edge planed. Fig. 267 will explain the process.

2. Mark out. Convex curves that are to be chiselled must be drawn fully. Holes that have to be bored need only have the centres marked.

3. Prepare fillet and saw off.

4. Bore all holes. All boring should be executed before sawing off waste, this also applies to the screw holes in the fronts.

5. Remove waste and vertically chisel all curves.

6. Clean off the back piece and attach bevelled fillets in position by means of glue and ½-in. finishing pins.

7. Clean off the fronts and attach them to the back; this should not be attempted until the glue on the fillets is quite dry.

8. Remove the waste end of fillets and clean off the sides of the model.

Demonstrations.—

1. Method of preparing the fillets to support front.
2. Chiselling curved tops, back and fronts.
3. Cutting holes in faces of fronts.
4. Cleaning off parts and fixing fillets.
5. Attaching fronts to back.

Lessons: Tools.—Principle of the cutting action of Forstner bits.

Extend previous lesson on brace and other tools used. Leverage of brace (see chapter on "Science").

Timber.—Question concerning woods used. Compare and contrast same. Growth of trees continued.

Calculations.—

1. Determine the area of the ¾-in. holes.

Rule.—Area of circle $=$ diameter $\times$ diameter $\times$ $\cdot 7854$ $=$ $D^2 \times \cdot 7854$.

2. Find the volume of material removed in boring the four holes in each front.

3. Determine the amount of material used by the class, in planking 9 in. wide.

4. Find the cost of each model.
   Wood A at *xd.* per foot super.
   Wood B at *xd.* per foot super.

5. Screws at *xd.* per gross.

6. Determine the internal volume of a box large enough to contain one model.

EXERCISE III

A TOWEL ROLLER

Exercises Involved.—Sawing and long planing. Planing to prismatic and cylindrical form. Formation of mortise-and-tenon joints with framing and *application of wedging.* Vertical chiselling (*a*) of flat surfaces; (*b*) convex surfaces; (*c*) concave surfaces. Filing. Boring. Gluing. Cramping. Wedging. Use of screws.

Instructions.—DRAWING.—Prepare a front elevation, plan, and end elevation as shown. The length being considerably greater than the width the principle of the centre break can again be explained and adopted.

Parts of the model afford excellent examples for more advanced exercises in isometric projection, i.e. one of the brackets, a portion of the framing or a complete end view as shown in chapter on "Principles of Projection".

Complete the list of tools and material.

Tools Required.—Ruler. Pencil. *Half-rip saw.* Jack plane. *Trying plane.* Try square. Gauge. Marking knife. Mortise gauge. Mortise chisel. Tenon saw. Firmer chisel. Bow saw. Gouge (scribing). Half-round file. Brace and centre bit. Shell bit. Countersink. Smoothing plane. *Cramp.* Hammer. Screwdriver (large).

Material Required.—Pine, poplar, or satin walnut.

For frame, two pieces 31 in. by 1¾ in. by 1 in.; for roller, one piece 20 in. by 1½ in. by 1½ in.; for brackets, one piece 9 in. by 3 in. by 1 in.; nails, four 1-in. finishing pins; screws, four 1¼-in No. 10; glasspaper; glue.

Benchwork.—STAGES.—

1. Prepare material.

The frame.—

2. Mark out position of mortises on the long rails and gauge same.
3. Mark off shoulders on cross rails and gauge tenons.
4. Make mortises and tenons and fit them together.
5. Set out ends of framing; cut and shape parts.
6. Clean off inner edges of framing. Glue, cramp, and wedge up.
7. When dry, clean cut-off projecting wedges and tenon and clean off the surfaces.

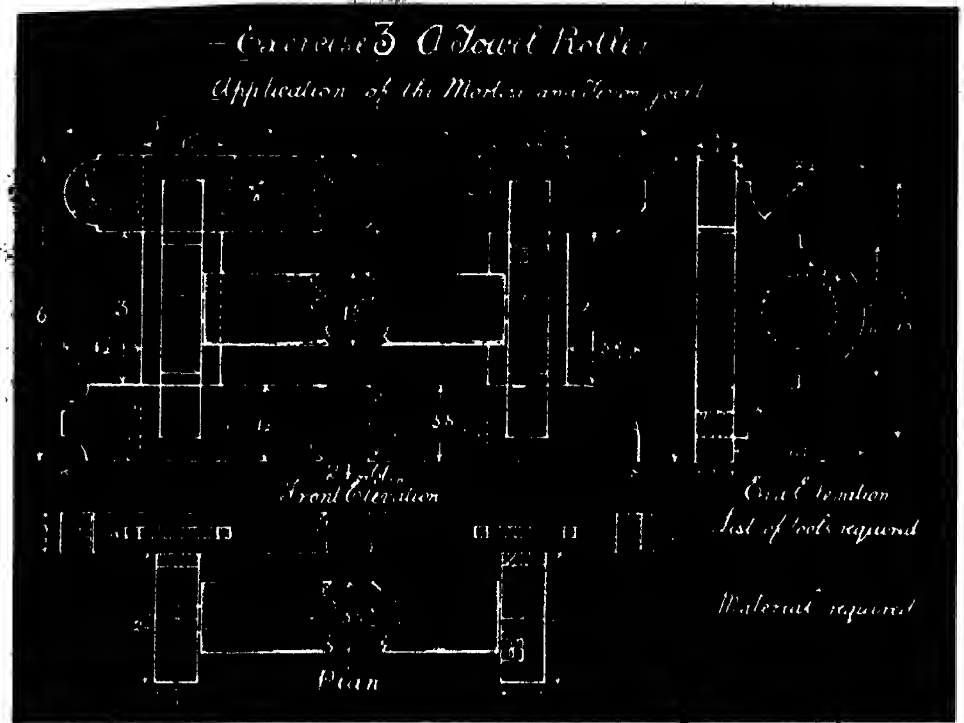
The brackets.—

8. Mark out as shown in sketch (fig. 268).
9. Cut out bracket with bow saw and pare back to the lines.
10. Bore holes and make notch in right bracket for pin of roller.
11. Clean off and attach to frame.

The roller.—

12. Set off shoulder lines on rectangular prism, and mark size of pins on the ends.
13. Cut to shoulder lines.

NOTE.—This must be done before planing the roller to its cylindrical



Exercise 3 A Towel Roller
Application of the Mortise and Tenon joint
Front Elevation
End Elevation
List of tools required
Material required
Plan

Fig. 268

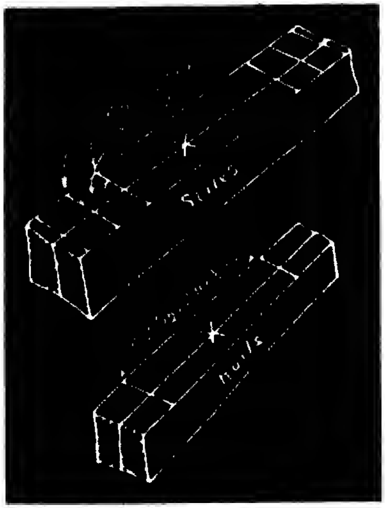


Fig. 269

form, in order to overcome the difficulty of cutting square shoulders on the cylinder.

14. Plane to cylindrical form as in round ruler.

15. Complete pins on ends. Glasspaper and fit in position.

Demonstrations.—

1. Setting out the framing.

NOTE.—The opposite rails must be paired when setting out mortise and shoulder lines in order to ensure the frame being rectangular; the accompanying sketches (fig. 269) will explain this.

2. Method of gluing—cramping and wedging.

The squareness of the frame must be tested by measuring the length of the inner diagonals by means of a thin rod of wood, as shown in diagram (fig. 270)—AC and BD must be equal. Any inequality can be adjusted by slight movements of the cramp. When the cramp is placed at a slight inclination to the sides of the frame it draws the framing to one side, thus varying the lengths of the diagonals. This must be attended to before driving in the wedges.

Fig. 270

The frames must be kept out of winding, i.e. the surfaces must be in the same plane. This can be assured by looking across the frame, the eye being in line with the surface.

3. Setting out, cutting, and fixing brackets in position.

To fix the brackets to the frame, proceed as follows: Draw the centre

NOTES

lines along and across the short rails; bore holes for the screws and mark pin holes as shown in fig. 271. Next proceed to draw the centre line on the back surface of each bracket, and, measuring from the centre point, mark the corresponding position of screw holes and pins. Now cut the heads off the finishing pins and drive them into the centre marks, as shown in sketch, leaving them protruding about $\frac{3}{8}$ in. Prick holes into the framing as indicated, then place the bracket in position on the frame, when it will be held in a central position and the work can be turned over and the screws inserted from the back of the frame.

Fig. 271

4. Method of marking out and cutting pins on end of roller.

Lessons: Tools.—Compare and contrast firmer chisels with gouges; cramp and application of the "Screw Principle". See chapter on "Science".

Compare and contrast nails and screws, and action of screw. See lesson on "Screws".

Timber.—Growth of trees continued, and felling. Material used in making model.

Calculations.—

1. Find the area of a face of one of the brackets.
2. Find the volume of a bracket, not taking into account the hole.
3. Find the area of the roller, not including the ends.
4. Find the volume of the roller, not including the pins.
5. Find the approximate weight of the model.
6. [illegible]rtain the approximate cost of the model.

EXERCISE IV

A SIMPLE INKSTAND

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Marking out. Sawing. *Paring large surface.* Boring. *Fluting with gouge.* Chamfering with chisel and plane. End-grain planing.

Instructions.—DRAWING.—Prepare a plan, side elevation, and section as shown.

Complete usual list of tools and material.

Tools Required.—Ruler. Pencil. Half-rip saw. Jack plane. Try square. Gauge. Marking knife. Compass. Tenon saw. Firmer chisel, 1-in. Brace and 1¼-in. centre bit. *1-in. firmer gouge.* Smoothing plane.

Material Required.—Pine or poplar, 1 piece 14 in. by 2¾ in. by 1⅜ in.

Benchwork.—STAGES.—

1. Prepare material and mark out work.
2. Saw and chisel the base.
3. Make the flute.
4. Bore the holes.
5. Chamfer the ends and edges.
6. Clean off surfaces and ends.

Demonstrations.—

1. Cutting and chiselling recess in bottom. (See chapter on "Chiselling Processes".)
2. Method of forming flute.

Lessons: Timber.—Material used for exercise. Felling and seasoning (natural method).

Tools.—The firmer gouge. Compare and contrast with other forms of chisels.

NOTE.—Explain the advantages of a block plane for end-grain planing as compared with a plane having the ordinary "pitch".

Calculations.—

1. Find the area of the top surface.
2. Find the area of one of the sides.
3. Find the volume of wood removed in forming the under recess.
4. Find the volume of each hole.

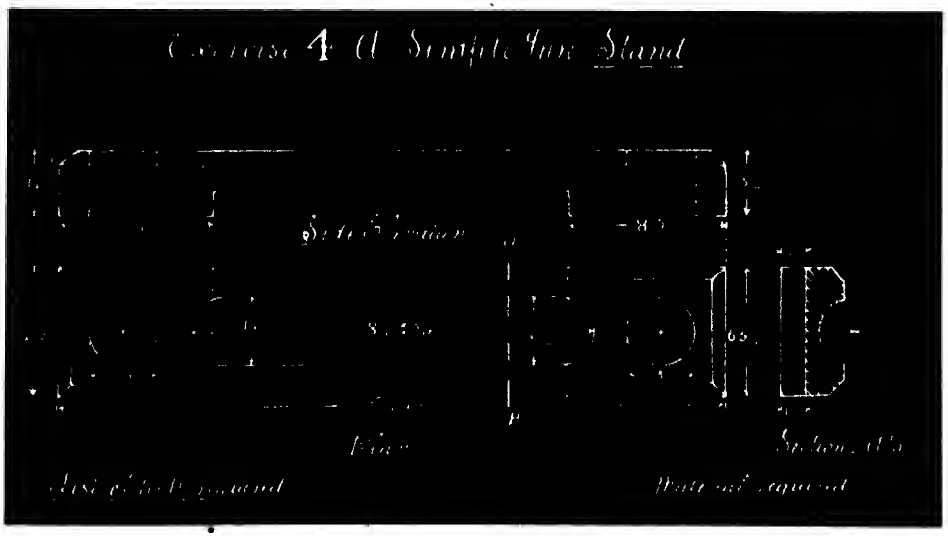


Fig 272

5. Find the volume of the complete model, including chamfers, but neglecting the flute.

6. Determine the amount of material required for a class of twenty boys to make this model. Ascertain the cost of same at *x*d. per foot super. of $1\frac{1}{4}$-in plank.

EXERCISE V

A BOOKSHELF

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. More difficult example in marking out. Bow sawing. Spokeshaving. Vertical chiselling (flat and curved). Stopped grooving. Boring. *Rebating*. Nailing. Screwing.

Instructions.—DRAWING.—Prepare the views shown. This model affords an advanced exercise in isometric projection. Complete the list of tools and material.

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Trying plane. Try square. Gauge. Marking knife. Compass. Tenon saw. Bow saw. Spokeshave. Chisels (various). Gouge (scribing). Mallet. *Side fillister*. Brace and $\frac{1}{2}$-in. centre bit. Bradawl. Smoothing plane. Hammer. Screwdriver.

Material Required.—This model may be made of pine, poplar, satin walnut, black walnut, mahogany, or teak. The shelf may be made of pine or poplar, having the front edge faced with hard wood, in keeping with the sides. Sides, one piece 20 in. by $5\frac{1}{4}$ in. by $\frac{9}{16}$ in.; shelf, one piece 24 in. by 5 in. by $\frac{7}{16}$ in.; hanging pieces, one piece 26 in. by $2\frac{1}{4}$ in. by $\frac{5}{16}$ in.; nails, fourteen 1-in. oval wire or finishing; screws, four $\frac{3}{4}$-in. No. 6; glue.

Benchwork.—STAGES.—

1. Prepare all material.
2. Prepare sides and mark out.

NOTE.—The side pieces are cut out and glued together, with a piece of paper between them, as shown (fig. 274). In this way the curves of both pieces are completed simultaneously, the grooves and rebates can be made; after which the pieces are easily separated by splitting the paper; they are then ready for cleaning off and fixing to the shelf.

3. Complete stopped grooves.
4. Saw, spokeshave, and chisel all curves, finishing with file and glass-paper.

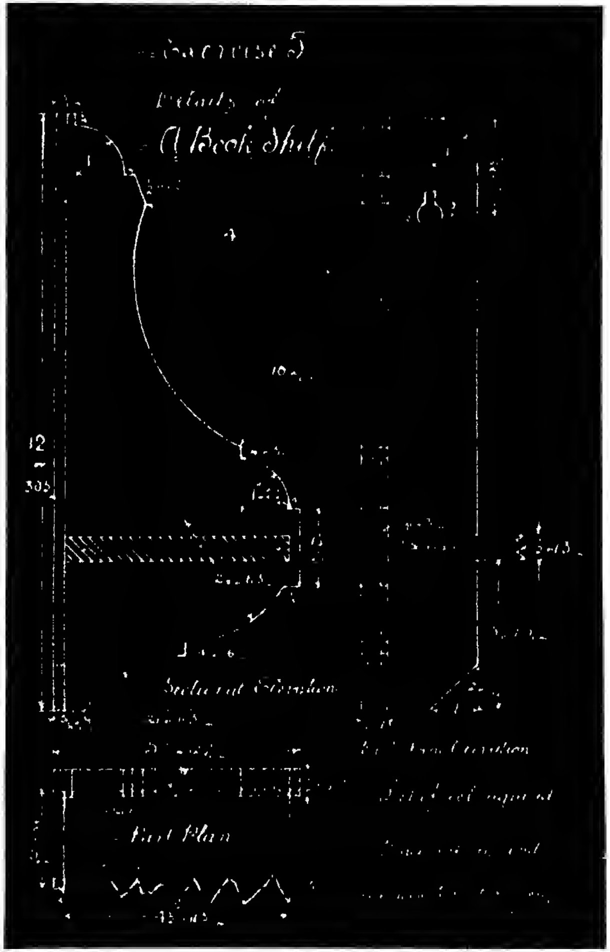

Exercise 5
Details of
A Book Shelf
Sectional Elevation
Part Plan

Fig. 273

5. Prepare rebates for hanging fillets; separate the parts and clean off.
6. Prepare shelf and clean off.
7. Prepare the hanging pieces.
8. Nail sides to shelf, applying a little glue to the ends. Nail hanging

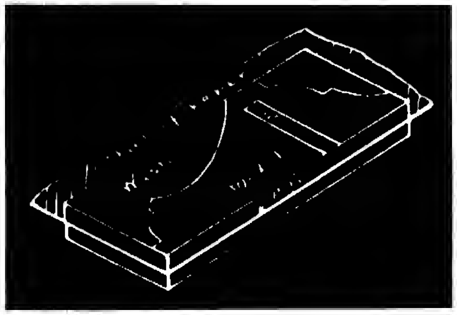


Fig. 274

pieces to sides. Screw hanging pieces to shelf, being careful to square shelf and hanging piece before inserting the screws.

Demonstrations.—

1. Method of gluing side pieces together, and marking out.
2. Use of side fillister for forming rebates.
3. Method of fixing parts together.

NOTE.—If the front edge of the shelf is to be faced with hard wood, it will be necessary to demonstrate the method of making the joint and gluing it together.

Lessons: Tools.—The fillister, parts and use of each. General questioning concerning tools used. Glue—brief outline of process of manufacture. Grinding, with reference to mechanical application of levers, &c. (simple form).

Timber.—Seasoning (artificial methods). Descriptive lesson on the particular timber used in making the model; if of hard wood, compare with other kinds for porosity, density, weight, colour, odour, toughness.

Calculations.—

1. Determine the quantity of material required by a class of x boys in making the model.

2. Determine the cost of the material at standard rates.
3. Find the cost of the model, including time and material.

		d.
Cost of timber		
Cost of nails, screws, glue		
Cost of labour: x hours at yd. per hour ...		
Total		

4. Determine the size of a case to hold six models conveniently packed.
5. Determine the size of a case to hold six models, the parts not being fixed together.
6. What saving in space and material will be effected by adopting the latter method?

EXERCISE VI

AN INLAID LAMPSTAND

Exercises Involved.—Marking out and sawing from the plank. Planing to dimension. *Butt jointing.* Marking out work. *Setting and using bevel. Using of router. Inlaying* (careful fitting).

Instructions.—DRAWING.—Prepare plan and sectional elevation. Complete list of tools and material.

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Trying plane. Try square. Gauge. Marking knife. Compass. Tenon saw. Brace and centre bits (various sizes). Mallet. Chisels (various). *Router. Bevel. Bench holdfast.* Hammer. Smoothing plane.

Material Required.—The base may be made of any suitable hard wood, and the inlay of coloured woods which contrast with the base and each other. The base of black walnut, with inlays of sycamore and mahogany, looks well.

Base, one piece (kind) 9 in. by $8\frac{1}{4}$ in. by 1 in.; inlay, one piece (kind) 15 in. by $1\frac{1}{4}$ in. by $\frac{3}{8}$ in.; inlay, one piece (kind) 15 in. by $1\frac{1}{4}$ in. by $\frac{3}{8}$ in.

Benchwork.—STAGES.—

1. Joint strips for inlay and lay aside to dry.
2. Prepare base and mark out octagon.
3. Cut and fit together pieces of inlay, and glue to a sheet of paper.

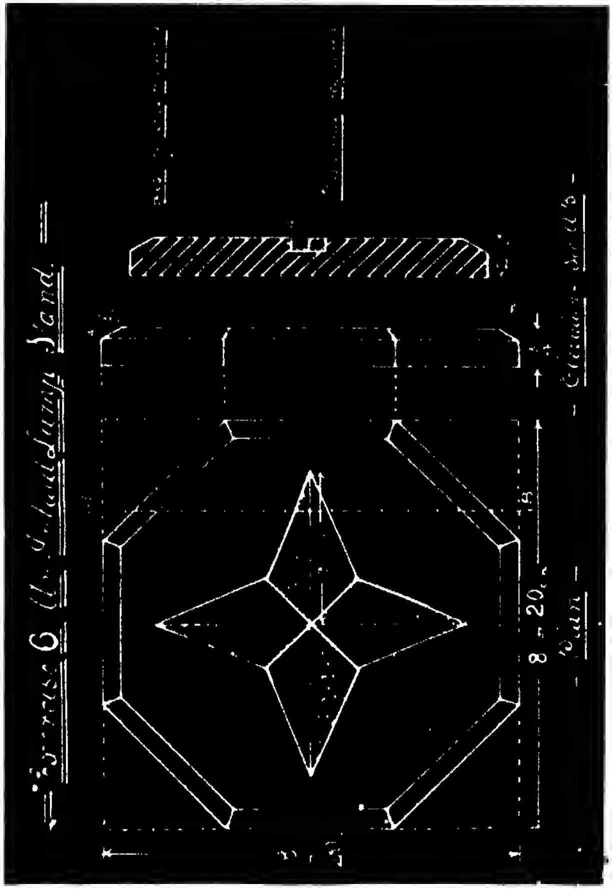


Fig. 275

4. Remove paper from inlay, clean off edges, lay in position on base, and mark position of recess; cut out recess, and glue inlay in position.

5. Cut out octagon, plane edges, mark out and make chamfers.
6. Clean off surfaces.

Demonstrations.—

1. Method of jointing inlay.
2. Method of fitting inlay together, the stages of which are indicated in figs. 276–277.
3. Method of making recess and fixing inlay.

Fig. 276

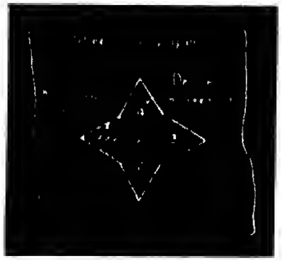


Fig. 277

NOTE.—The bulk of the material is easily removed by boring a number of holes with centre bits of various sizes; this is followed by chiselling and use of router. For cleaning out the acute corners a chisel ground "very thin" and used sideways is essential.

Lessons: Tools.—The bevel, and method of setting to various angles. The router, parts and varied use. Bench holdfast, explain parts and mechanical principles involved.

Timber.—Woods used and geographical position. Seasoning—artificial methods continued. Glue—further details on method of manufacture.

Calculations.—

1. Determine the amount of 1-in. plank, of suitable width, required by a class of x boys for making the model.
2. Determine the amount of planking of each kind required for the inlay.
3. Ascertain the cost of such material at standard rates.
4. Compare the volume of the piece supplied for the base with the volume of the complete model, and determine the amount of waste.
5. How many cubic feet of timber are contained in a log of wood 12 ft. long, having a sectional area 9 in. by 6 in.?

6. Determine the weight of the foregoing log, having found by experiment the weight of a superficial foot 1 in. thick.

NOTE.—Apply this to the particular wood used in making the model.

EXERCISE VII

A BREAD BOARD

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. *Marking out of ellipse and determining normals and tangents.* Use of *compass saw.* Bow sawing. More difficult example in spokeshaving. *Curved chamfering.* Cleaning off.

Instructions.—DRAWING.—Draw plan, part end elevation, and section.

NOTE.—The working details, as shown in the accompanying plate, will not be drawn; they should, however, be very carefully explained. The terms as applying to the ellipse should be thoroughly taught.

To an advanced class a simple explanation of the conic section may be given.

Complete list of tools and material.

Tools Required.—Ruler. Pencil. Half-rip saw. Panel saw. Try square. Gauge. Marking knife. Compass saw. Bow saw. Spokeshave. File. Firmer chisel. Smoothing plane. Bench holdfast.

Material Required.—Pine, poplar, hickory, or lime; one piece, 14 in. by 9¼ in. by 1 in.

Benchwork.—STAGES.—

1. Prepare material.
2. Mark out, using pins and thread as shown.
3. Cut the side curves with a bow saw, and finish with spokeshave, chisel, and file.
4. Cut the horns and plane the cut surface.
5. Mark out chamfers, using pencil and thumb gauge as shown.
6. Chamfer the curves, using spokeshave and chisel.
7. Chamfer horns and clean off surfaces with smoothing plane.

Demonstrations.—

1. Method of marking out ellipse and setting out horns.
2. Method of using the compass saw.
3. Method of working curved chamfers. (See chapter on "Chiselling Processes".)

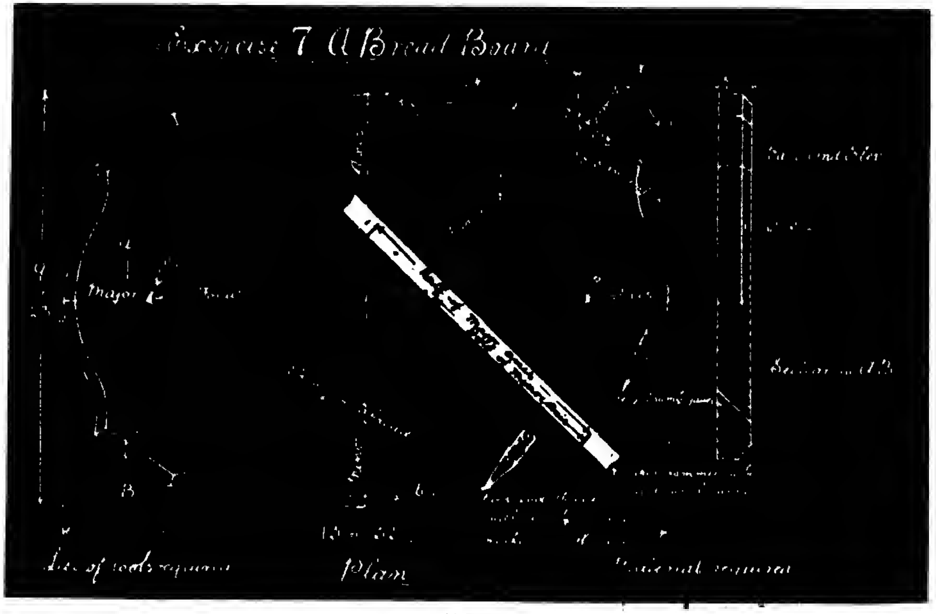


Fig. 278

NOTES

Lessons: Tools.—The compass saw, and comparison with other kinds. Further details on spokeshave, and uses to which applied. The bench holdfast.

Timber.—Notes on the particular wood used. Methods of converting logs: advantages and disadvantages of each.

Calculations.—

1. Find the area of the ellipse.

$$\textit{Rule.}\text{—Area} = \text{Major axis} \times \text{Minor axis} \times \cdot 7854.$$

2. Find the volume of the elliptical base.
3. Determine the length of the outer edge. (Use a piece of string.)
4. Find the number of models that can be made from a plank 15 ft. long and 14 in. wide.

NOTE.—The grain of the wood to run in the direction of the major axis.

5. Compare the area of the face of the finished model with the area of the piece of wood supplied, and ascertain the amount of waste entailed in making the model.
6. Determine the cost of the material used in making x models at yd. per foot super., and find the relative costs of finished model and waste.

NOTE.—Substitute values for x and y.

EXERCISE VIII

AN OXFORD PICTURE FRAME

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Setting out work. Application of half-lapped joints. *Formation of stopped rebates with chisel.* Chamfering with and across the grain. *Stopped chamfering.*

Instructions.—DRAWING.—Prepare the views shown. Explain the sections by the aid of a model cut to the various section lines. Complete the lists of tools and material.

Tools Required.—Ruler. Pencil. Half-rip saw. Jack plane. Trying plane. Try square. Gauge. Marking knife. Tenon saw. Firmer chisel, $\frac{1}{2}$-in. and $\frac{3}{4}$-in. or 1-in. *Cutting gauge.* Mallet. Smoothing plane.

Materials Required.—Satin walnut, black walnut, or teak; one piece (*length*) by 1 in. by $\frac{3}{4}$ in.; 1 piece (*length*) by 1 in. by $\frac{3}{4}$ in.

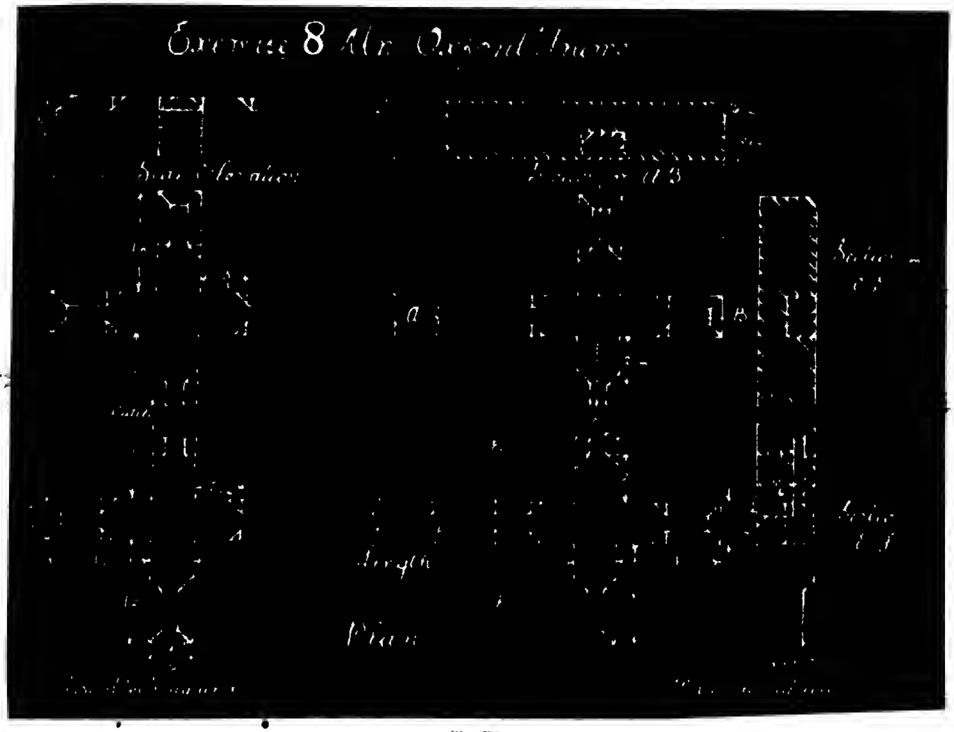


Fig. 279

NOTE.—The dimensions of the frame can be varied; scholars who possess a certificate might make the frame in keeping with the dimensions of such certificate.

Benchwork.—STAGES.—

1. Prepare material.
2. Mark out joints and chamfers; cut and fit half-lapped joints.
3. Whilst frame is together, gauge the rebates. Chisel rebates. (See chapter on "Chiselling Processes".)
4. Work all chamfers.
5. Clean all inner edges, glue the joints, and clean off surfaces.

Demonstrations.—

1. Method of marking out joints and chamfers.
2. Gauging and chiselling rebates.
3. Formation of stopped chamfers.

Lessons: Tools.—General review of tools used, advancing each a stage.

Timber.—Description of wood used. Defects in timber.

Calculations.—

1. Compare the volume of the rough material supplied for the exercise with the volume of material when planed.
2. Determine the volume of material removed in forming the rebates.
3. Find the area of the glass required, and express same as the fraction of a square foot.
4. Determine the total length of the chamfers.
5. Find the volume of the material removed in forming the chamfers.
6. Determine the total volume of the finished model.

EXERCISE IX

A CORNER BRACKET

Exercises Involved.—Marking out and sawing from the plank. Planing large surfaces. More difficult exercise in marking out curved work. Stopped grooving. Bow sawing. Spokeshaving. Vertical chiselling of flat and curved surfaces. *Stopped chiselling of curved surfaces.* Nailing. Screwing.

Instructions.—DRAWING.—Prepare a plan and elevation as shown. Explain tangent curves and method of finding centres. Complete list of tools and material.

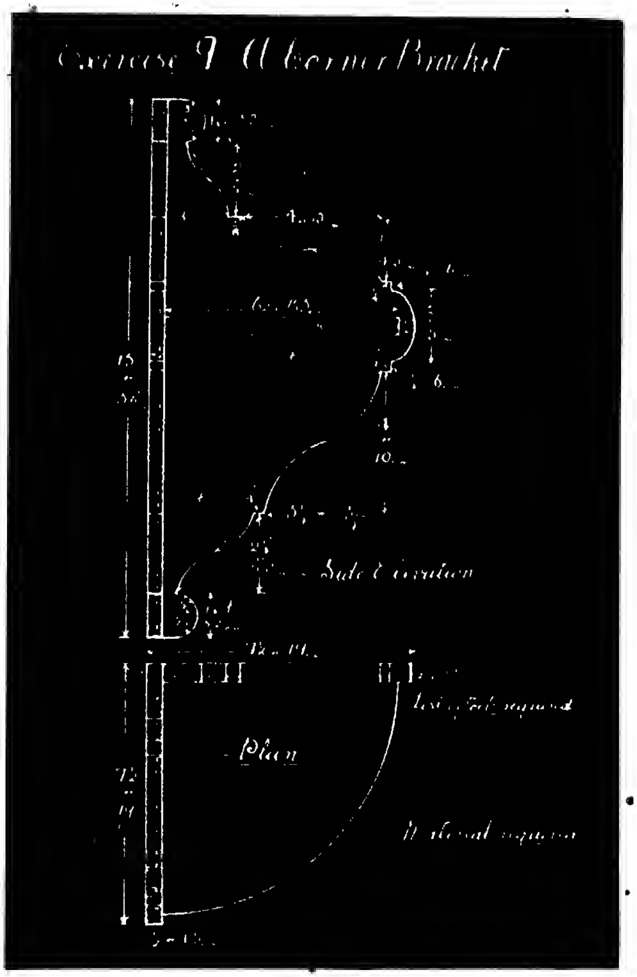


Fig. 250

NOTES

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Try square. Gauge. Marking knife. Compass. Mallet. Firmer chisel. Bow saw. *Pad saw.* Spokeshave. Router. Bench holdfast. Smoothing plane. Bradawl. Screwdriver. Hammer.

Material Required.—Pine. Poplar. Satin walnut. Black walnut. Cedar or mahogany. One piece 31 in. by $7\frac{5}{8}$ in. by $\frac{3}{8}$ in.

Benchwork.—STAGES.—

1. Prepare material and mark out as shown in figure.
2. Glue together the pieces for the sides, having layer of paper between, and mark out curves and grooves.
3. Cut and form stopped grooves.
4. Saw, spokeshave, chisel, file, and glasspaper curved edges.

NOTE.—Care must be taken when glasspapering the curves to keep the surface square with the face. Scholars have a great tendency to roll the glasspapering stick and thus produce unsightly curvature in both directions.

5. Prepare the shelf.
6. Reduce the width of one of the side pieces by an amount equal to the thickness of the material in order to balance the sides. Clean off, fit, and fix the parts together.

Demonstration.—Method of finishing the curves with the chisel in places where the spokeshave cannot be used.

Lessons: Tools.—The pad saw, parts and uses. Further notes on tools in general use.

Timber.—Description of timber used. Dry rot in timber—cause and prevention.

Calculations.—

1. Find the cost of material used at standard rate.
2. Find the area of the shelf.
3. Find the volume of the shelf.
4. Find the area of the side pieces.

NOTE.—Obtain some squared paper, i.e. paper divided in inches with eighths or tenths. Lay each side piece on the paper and mark round outer edge, then count the squares, thus determining the area.

5. Calculate the volume of the complete model.
6. Determine the volume of a box, made of $\frac{3}{8}$-in. material, that will just contain one model.

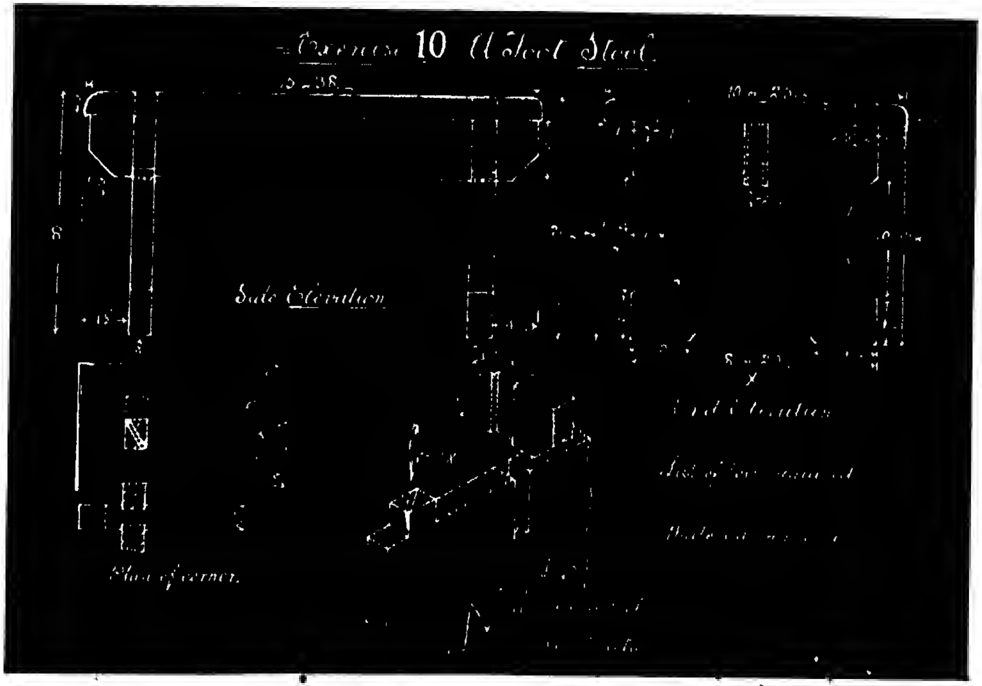

Exercise 10 A Tool Steel.
Side Elevation
End Elevation
Plan of corner.

Fig. 281

EXERCISE X

A FOOTSTOOL

Exercises Involved.—Marking out and sawing material from the plank. Planing to dimensions—large surfaces. Marking out work. *Formation of bridle joint.* Bow sawing and spokeshaving. Mortising. Tenon cutting. Edge rounding. Gluing and *diagonal wedging.* More difficult example of building up and cleaning off.

Instructions.—DRAWING.—Prepare side and end elevations and part plan, as shown. The details of construction may be shown in isometric projection. Complete the lists of tools and material.

Tools Required.—Ruler. Pencil. Half-rip saw. Panel saw. Jack plane. Trying plane. Try square, 4½ in. and 10½ in. Gauge. Marking knife. Tenon saw. Bow saw. Spokeshave. Mallet. Chisels (various). Hammer. Smoothing plane.

Material Required.—Pine or poplar is suitable for this model; for the top, one piece 16 in. by 10¼ in. by ⅞ in.; for the legs, one piece 17 in. by 8¼ in. by ⅞ in.; for the rail, one piece 16 in. by 2¼ in. by ⅞ in.

Benchwork.—STAGES.—

1. Prepare material.
2. Mark out all work.
3. Cut and shape legs.
4. Cut, shape, and fit rail to legs.
5. Mortise top and fit to legs, cut to length, clean ends and round edges.
6. Make cuts in tenons for wedges, clean all surfaces, glue and wedge together.

Demonstrations.—

1. Method of marking out legs and cutting tenons.
2. Method of marking mortises in top.
3. Method of gluing together.

Explain principle of wedging and reason for diagonal arrangement.

Lessons: Tools.—The half-rip saw. Compare with other saws—reason for large teeth—pitch of teeth and amount of set.

Timber.—Questions concerning timber used. Methods of preserving timber—(*a*) in damp situations; (*b*) in dry situations.

NOTES

Calculations.—

1. Find the area of the top surface.
2. Calculate the volume of the rail.
3. Find the area of one of the large faces of a leg.

NOTE.—Area of curved recesses to be found by using squared paper.

4. Calculate the volume of material in each leg.
5. Determine the cost of the material used in making twelve stools.
6. Compare the total volume of the material used with the volume of a box that shall just contain the model.

REMARK.—The top of the stool looks well if inlaid with some simple design. The teacher must use discretion in this matter. Any apt pupil may be allowed to carry out such inlaying, and original designs for such should be encouraged.

EXERCISE XI

A MIRROR FRAME

Exercises Involved.—Marking and sawing from the plank. Planing to dimensions. More complicated example in marking-out work. *Stopped mortising.* Tenon cutting. *Cutting shoulders in varying planes.* Rebating. Boring. Bow sawing. Spokeshaving. Vertical chiselling (flat and curved surfaces). *Stopped dovetailed grooving.* Chamfering. Gluing and cramping. Nailing. Screwing.

Instructions.—DRAWING.—Prepare front elevation, sectional elevation, part side elevation as shown, and add a plan. A working detail of any of the parts may be drawn in isometric projection. Complete lists of tools and material.

Tools Required.—Ruler. Pencil. Half-rip saw. Panel saw. Jack plane. Trying plane. Try square. Gauge. Marking knife. Mortise gauge. Mortise chisel. Mallet. Tenon saw. Side fillister *or sash fillister. Rebate plane.* Brace and Forstner bits. Bow saw. Spokeshave. Firmer chisel. Smoothing plane. Bradawl. Hammer. Brad punch. Screwdriver.

Material Required.—Satin walnut or black walnut, two pieces $25\frac{1}{2}$ in. by $1\frac{5}{8}$ in. by 1 in.; one piece 23 in. by $3\frac{1}{4}$ in. by $\frac{3}{8}$ in.; one piece 9 in. by $1\frac{3}{4}$ in. by $\frac{3}{8}$ in.; screws, four $1\frac{1}{4}$-in. No. 8; nails, six 1-in. oval wire; glue; glass-paper.

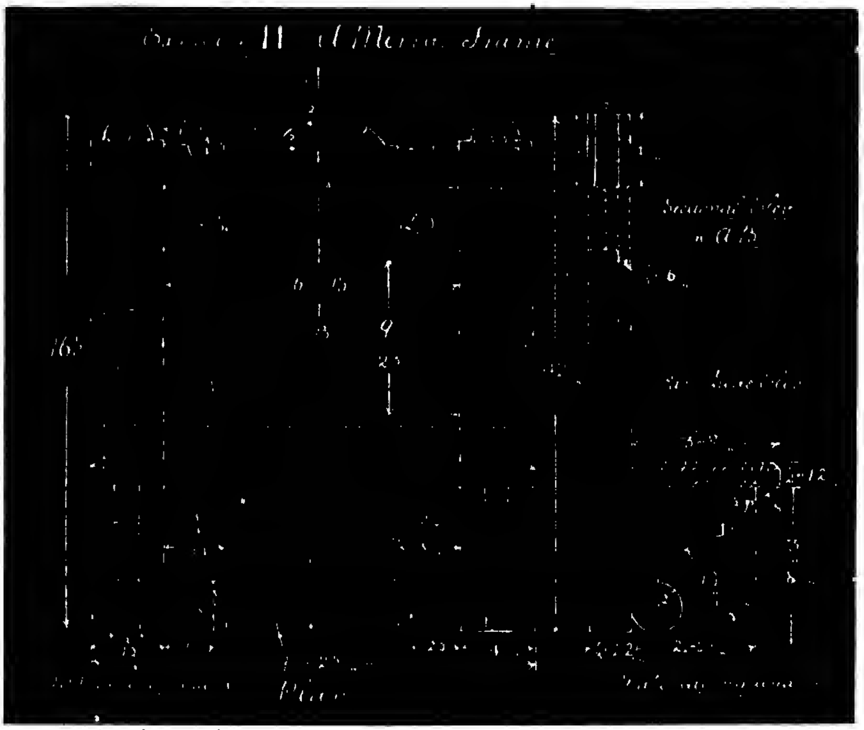


Fig. 283

Benchwork.—STAGES.—

1. Prepare material.

2. Set out rails and stiles (pair each). Gauge mortises and tenons. Make mortises and cut tenons.

NOTES

NOTES.—

(*a*) The shoulders must not be cut until the rebating is completed.

(*b*) In setting out the rails and stiles allowance must be made for the amount that will be rebated off the width of the pieces. See sketch (fig. 283).

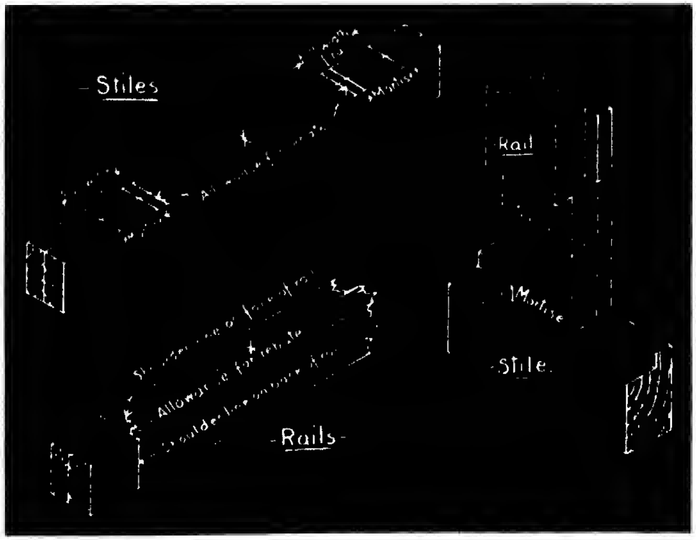


Fig. 283

3. Rebate stiles and rails. Cut shoulders on rails and fit together.

4. Clean inner edges, glue and cramp together. When dry, clean off surfaces. Mark out top, cut and pare same.

5. Prepare pediment and apron and fix in position by means of brads.

6. Prepare shelf and supports. Clean off and glue together.

7. Bore screw holes and fix shelf and supports to frame.

Demonstrations.—

1. Method of marking out and making stopped mortises.
2. Method of rebating pieces.

3. Gluing. Cramping. Squaring and cleaning off frame.
4. Formation of stopped dovetail grooves for shelf supports.
5. Fixing apron, pediment, and shelf.

Lessons: Tools.—Sash fillister, if used. Explain parts and use of each. Mortise gauge; further remarks.

Timber.—Further notes on methods of preservation. Question concerning the particular kind of wood used. Further notes on nails. Screws. Glue.

Calculations.—

1. Find the volume of the top rail.
2. Find the volume of one stile.
3. Find the area of the pediment. } Use squared paper.
4. Find the area of the apron. } Use squared paper.
5. Find the area of one support. } Use squared paper.
6. Determine the cost of the material consumed.

EXERCISE XII

A WOODEN SPOON

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Marking out work. Bow sawing. Spokeshaving. *Surface modelling of concave and convex surfaces.* Filing and glasspapering.

Instructions.—Drawing.—Prepare a plan, side elevation, and sections as shown. Explain (*a*) the method of finding the centre of a curve, having given the length of the chord and pitch of the arc; (*b*) tangent arcs which envelop one another.

Complete list of tools and material.

Tools Required.—Ruler. Pencil. Panel saw. Try square. Gauge. Marking knife. Compass. Bow saw. Spokeshave. Firmer chisel, 1-in. *Carving gouge. Files with safe edge.*

Material Required.—Lime or birch, one piece 13 in. by $2\frac{3}{4}$ in. by $\frac{7}{8}$ in.

Benchwork.—Stages.—

1. Prepare and mark out material.
2. Saw and shape to outline.
3. Gouge interior and mould exterior of spoon.
4. Shape and finish handle.
5. Glasspaper all surfaces.

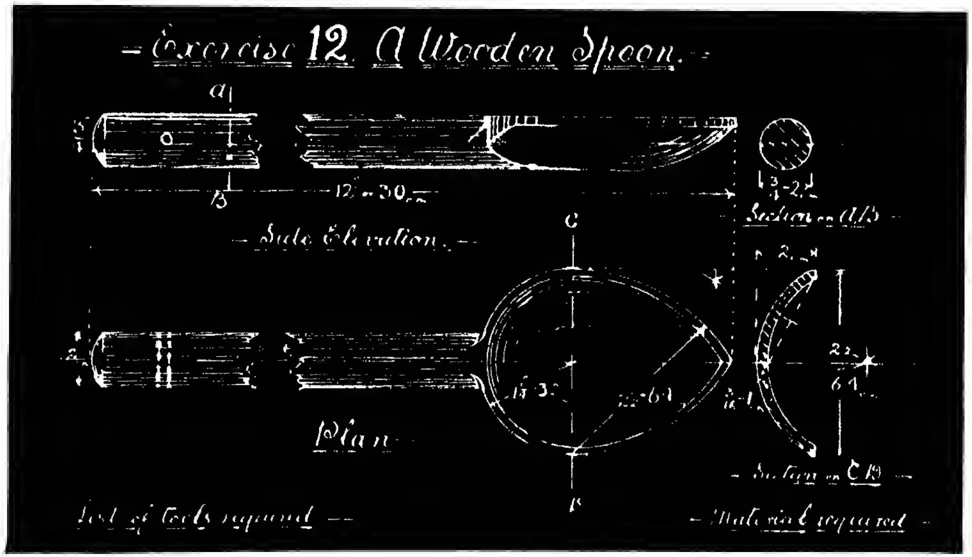

Exercise 12. A Wooden Spoon.
Side Elevation.
Section on AB
Plan
Section on CD
List of tools required
Material required

Fig. 284

Demonstration.—

Method of modelling surfaces.

Lessons: Tools.—Files. General outline of method of manufacture. Names of parts. Use of safe edge.

Material.—Brief résumé of various lessons given throughout the year.

Calculations.—

Find the volume of the completed spoon.

NOTE.—This cannot be conveniently worked as in previous examples. It will prove very instructive and useful to the scholars if the following methods are demonstrated:—

(*a*) Having planed the piece of wood ready for marking out, calculate its volume and carefully weigh the piece and record the weight. When the model is complete, weigh it and compare the weight of the finished article with the weight of the piece from which it was made, and in this way ascertain the volume. This can be expressed in terms of their ratio as follows:—

As the weight of the original piece A is to the volume of the original piece B, so is the weight of the finished article C to the volume of the finished article X.

$$A : B :: C : X$$

(*b*) *By displacement.*—Obtain the loan of a graduated flask. Partly fill with water, and note the volume of same. Sink the spoon in the water, and note rise in level. The difference in volume represents the volume of the spoon.

NOTE.—If a sinker be used, its volume must be calculated and allowed for.

COURSE III

EXERCISE I

A SIMPLE DOVETAILED JOINT

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Marking out. Splay sawing. Shoulder cutting. Clearing of slot. Accurate fitting. Cleaning off.

Instructions.—DRAWING.—Allow the scholars to measure the teaching model and ascertain the dimensions of the parts.

NOTE.—It provides an excellent training in the third-year course to make the scholars prepare freehand sketches of the exercises to be worked, and write upon them all the dimensions. From these sketches the scholars should proceed to execute their finished drawing.

Prepare (*a*) plan, front and side elevation; (*b*) isometric projection (open or closed). Complete list of tools and material.

Tools Required.—Ruler. Pencil. Half-rip saw. Jack plane. Try square. Gauge. Marking knife. Tenon saw. Firmer chisel, ½-in. Mallet. Smoothing plane. (*Bow saw.*)

Material Required.—One piece of poplar or pine 12 in. by 2¼ in. by 1 in

Benchwork.—STAGES.—

1. Prepare material.
2. Mark off the length of each piece.
3. Mark and line off slot with pencil, and set out slot.
4. Mark shoulder line of pin (cut line).
5. Cut the sides of the slots but do not remove the waste.
6. Fix the piece which is to carry the pin in the vice, and on it lay the piece which contains the slot The correct position of the pin can then be marked with the tip of the tenon saw, as indicated in accompanying figure (286).

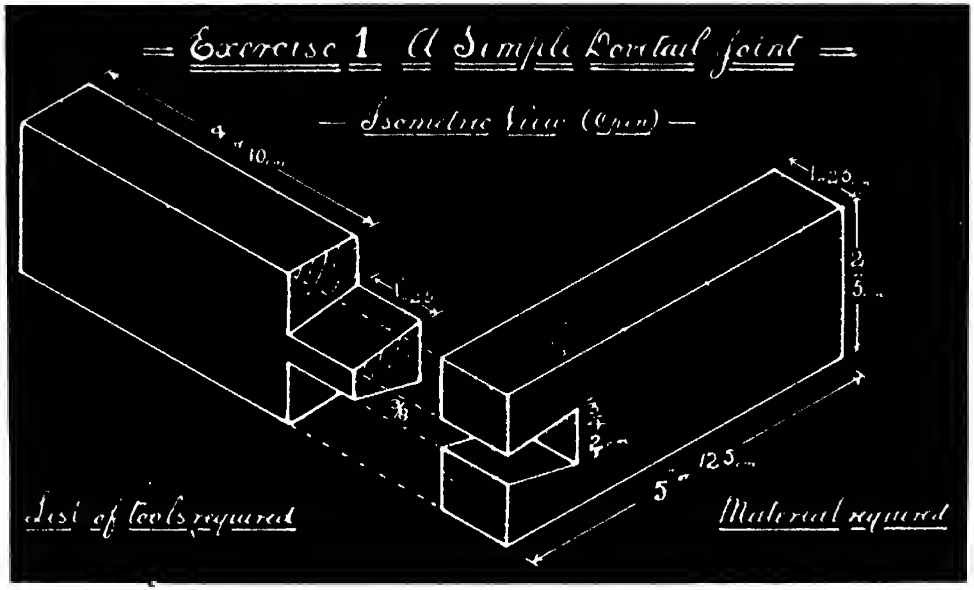

Exercise 1
Isometric View (Open)
List of Tools required
Material required

Fig. 295

NOTES

7. Remove waste from slot. This can be accomplished in various ways.
(a) By mortising (fig. 287).
(b) By boring a centre-bit hole and chiselling back to the line (fig. 288).

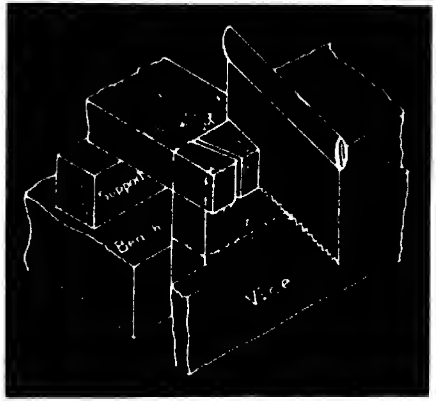


Fig. 286

(c) By cutting out main portion of the waste with the aid of a bow saw. afterwards chiselling back to the line (fig. 289).
8 Cut pin.

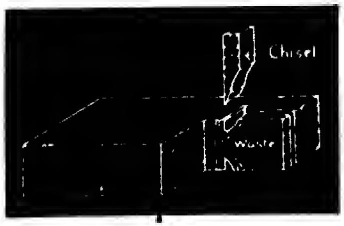


Fig. 287

NOTE.—First saw down the grain square with the shoulder line. Care should be taken to keep the kerf just to the outside of the marks made by the tip of the saw when marking out the pin. (See fig. 286.)

NOTES

9. Cut the shoulders and slightly chamfer the edges of the pin.
10. Fit together, remove waste end, and clean off surfaces.

Fig. 288

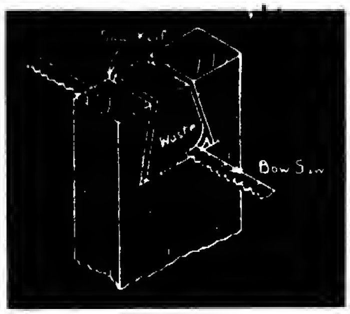


Fig. 289

Demonstrations.—

NOTE.—This being the first exercise in dovetailing (box form), care should be taken to explain carefully every detail connected with the process.

1. Method of marking out and sawing slot.
2. Method of marking pin.
3. Removing waste from slot.
4. Cutting pin.
5. Fitting together and cleaning off.

Lessons: Timber.—

NOTE.—In this course the teacher should aim at reviewing the previous lessons, going more into detail with each.

Germination of seeds. Conditions necessary. Use of cotyledons. Function of roots. Transmission of sap to and from the leaves. Function of leaves. Bast fibres. Cambium layer. Medullary rays.

Tools.—The tenon saw—special shape of teeth and reason for same. Method of setting and sharpening.

Calculations.—Simple problems on areas and volume as in previous examples.

Determine, graphically, the horizontal and vertical components of a force of 15 lb. applied to the handle of a tenon saw as in diagram (fig. 290).

NOTES

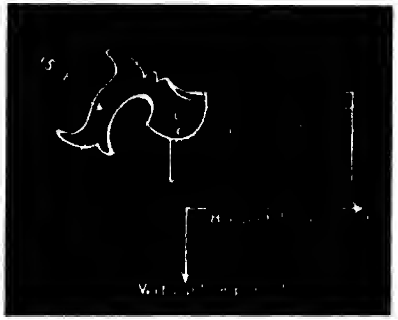


Fig. 290

EXERCISE II

A HAT RAIL

Exercises Involved.—Marking out and sawing from the plank. Long planing. Marking out (tangent circles—enveloping). Mortising. Chamfering with plane. Curved chamfering with chisel. Ornamental cutting and shaping. Gluing and wedging.

Instructions.—DRAWING.—Allow scholars to examine the teaching model and prepare a rough working sketch, then proceed to execute the three views shown.

NOTE.—It is unnecessary to draw the complete model. All the detail is contained in one end, but a statement must be included showing the number of pegs and the distance between the centres.

This model would afford an advanced exercise in isometric projection.

Complete the list of tools and material.

Tools Required.—Ruler. Pencil. Half-rip saw. Jack plane. Trying plane. Try square. Gauge. Marking knife. Compass. Bow saw. Tenon saw. Firmer chisels (various). Brace and ⅜-in. centre bit. Spokeshave. Mallet. File. Hammer. Smoothing plane.

Material Required.—This model should in most cases be made of hard wood, as oak, black walnut, satin walnut, ash.

NOTES.

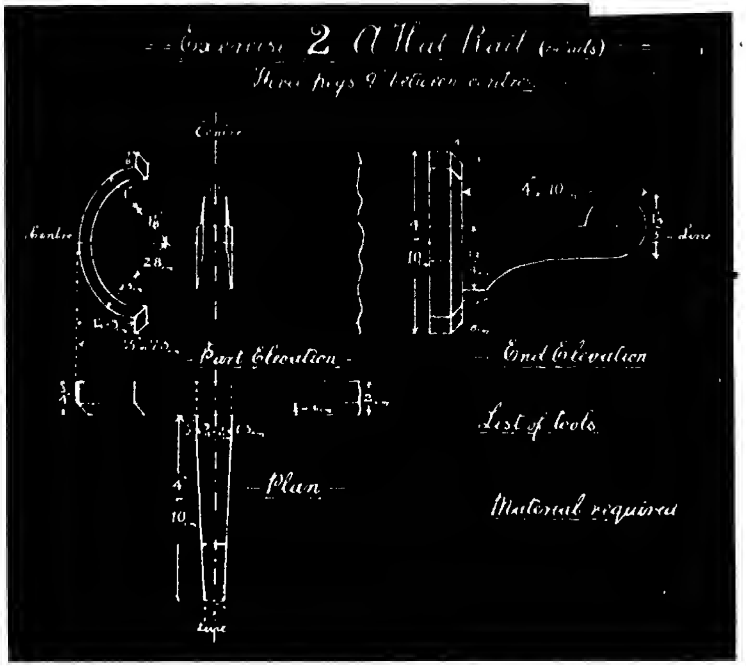


Fig. 291

One piece for the back 2 ft. 10 in. by 4¼ in. by ⅞ in.; one piece for the pegs 15 in. by 2¼ in. by ⅞ in.; glasspaper and glue.

Benchwork.—STAGES.—

1. Prepare material.
2. Mark outline of back and mortises.
3. Cut and shape back.
4. Mark out and chamfer back.
5. Mark out, cut, and shape pegs.
6. Clean surfaces; fit and glue pegs

NOTE.—The mortises should be made slightly larger at the back, and the pegs fixed in position by means of diagonal wedges.

Demonstrations.—

1. Method of marking out the curved ends.
2. Making the mortises.

NOTE.—For making mortises of this character a hole should first be bored, using a centre bit. The sides and ends can then be squared with a chisel.

3. Shaping the pegs.
4. Cleaning off and finishing.

Lessons: Timber.—Time for felling. Methods adopted in different countries. Method of bringing timber to the various ports. Importance of rivers.

Tools.—Question concerning tools used.

Saws.—Demonstration on method of setting and sharpening.

Calculations.—Determine by experiment (*a*) the amount of tension set up in the blade of a bow saw; (*b*) the amount of compression in the centre beam of the bow saw. (See chapter on "Science in Manual Training".)

EXERCISE III

A COMMON BOX DOVETAILED JOINT

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Marking out—use of bevel. Accurate sawing and fitting.

Instructions.—DRAWING.—Prepare either (*a*) an isometric projection as shown, or (*b*) three views in orthographic projection.

Complete the list of tools and material.

Tools Required.—Ruler. Pencil. Half-rip saw. Panel saw. Jack plane. Try square. Gauge. Marking knife. Bevel. Tenon saw. Bow saw. Firmer chisels (various). Mallet. Smoothing plane.

Material Required.—Pine or poplar; one piece 12 in. by 4¼ in. by ⅞ in.

Benchwork.—STAGES.—

1. Prepare material.
2. Mark off shoulder lines.
(It is advisable to use pencil for this.)
3. Mark out and cut pins.

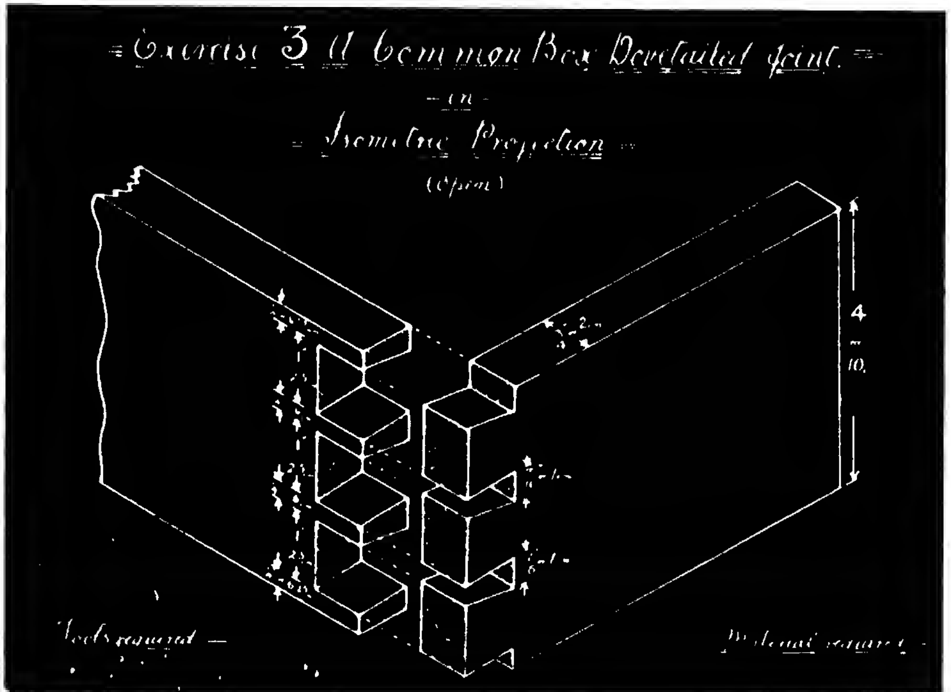

Exercise 3 A Common Box Dovetailed Joint.
— in —
Isometric Projection
(Open)
4
10.
Tools required —

Fig. 208

NOTE.—In the previous exercise on dovetailing the slot was first sawn and the pin marked from the slot; this method is suitable when only one pin has to be cut. When there is a number of pins it is usual to cut the pins first; when these are completed they are rested in position on the piece which is to carry the slots, and the positions of the slots are then marked either with a sharp pencil or a scribing point. This method enables the operator to observe more clearly whether the pieces are in correct relative position.

The previous method can of course be adopted if desirable. When similar pieces are being dovetailed, they are often cramped together and all slots cut at once. When this is done it is clear that the slots must first be cut and the pins marked from them as described.

4. Mark out and cut slots.
5. Fit together and clean off.

Demonstration.—

1. Marking out and cutting pins.

NOTE.—For removing the waste between the pins it is much quicker and more convenient to use a bow saw. The cut can be made very close to the shoulder line, thus enabling the shoulder to be finished by the aid of a fine paring cut. When the waste is removed by mortising, there is a tendency for the material to burst out at the centre. Also with beginners there is a tendency to chisel the shoulder very hollow, thus presenting a good fit on the surface whilst inside it is hollow. This constitues bad workmanship.

2. Marking out and cutting slots.
3. Fitting together and cleaning off.

Lessons: Timber.—Conversion of timber from log to plank. How accomplished. Methods of distribution to the various markets. Chief timber ports.

Tools.—The brace. Determine experimentally the force that must be exerted on the crank of the brace to bore holes of varying sizes in any given material.

This can be approximately gauged by means of a spring balance.

Process.—Bore a hole in a piece of wood, and note carefully the amount of effort required. Next attach one end of a spring balance to the crank of the brace, the other end being attached to a rigid beam. Now pull on the crank of the brace, being careful to exert a force similar to that applied when boring the hole. A second operator can take the readings on the spring balance. The experiment should be repeated three or four times, and the mean reading taken.

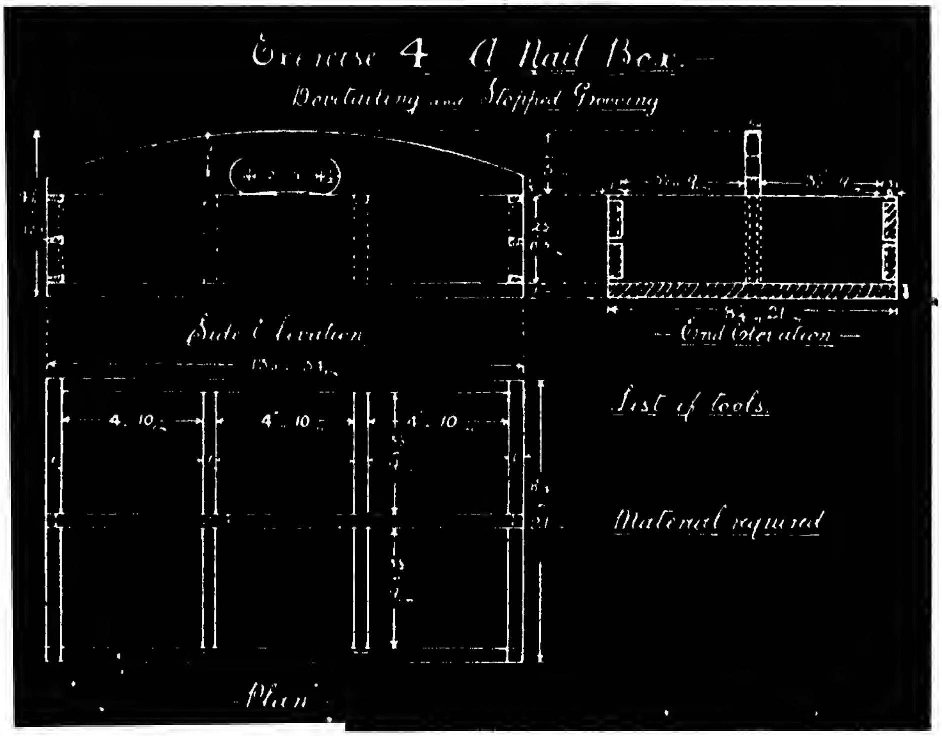

Exercise 4 A Nail Box.
Dovetailing and Stopped Grooving
Side Elevation
End Elevation
List of tools.
Material required
Plan

Fig. 398

EXERCISE IV

A NAIL BOX

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Stopped grooving. Dovetailing. Shaping with bow saw and spokeshave. Boring and shaping. Gluing. Screwing. Nailing.

Instructions.—DRAWING.—Prepare a plan, side elevation, and end elevation as shown.

NOTE.—This could be drawn to scale, half or three-quarter full size.

Complete the list of tools and material.

Tools Required.—Rule. Pencil. Panel saw. Jack plane. Trying plane. Try square. Gauge. Marking knife. Tenon saw. Bow saw. Firmer chisels (various). Spokeshaves (iron and wood). Brace and 1-in. centre bit. Mallet. Router. Smoothing plane. Bradawl. Hammer. Nail punch. Screwdriver.

Material Required.—American white pine or poplar; two pieces (each for one side and one end) 23 in. by 2¾ in. by ½ in.; one piece (centre partition) 14 in. by 4¾ in. by ½ in.; one piece (small cross partitions) 16 in. by 2¾ in. by ½ in.; one piece (bottom) 14 in. by 8½ in. by ½ in.; nails, eight 1-in. oval wire; screws, ten ¾-in. No. 6; glasspaper; glue.

Benchwork.—STAGES.—

1. Prepare all material.
2. Mark out ends and cut pins and grooves.
3. Mark out sides and cut slots and stopped grooves.
4. Mark out, cut, and shape centre partition.
5. Mark out, cut, and fit small cross partition.
6. Clean off inner faces; fit together and glue up.
7. Carefully mark position of screw holes in bottom, bore holes, and screw the bottom on.

NOTE.—The under edges of the work should first be carefully cleaned off with a smoothing plane and tested with a straightedge to ensure having all the edges flat and in the "same plane".

8. Clean off outer surfaces.

Demonstrations.—None are required for this exercise. The teacher should, however, explain in a general way the method of procedure. This can best be accomplished by a process of questioning rather than direct "telling".

Lessons: Timber.—Seasoning timber (*a*) in the log, (*b*) when cut into planks, (*c*) when sawn into thin boards, (*d*) when framed into articles.

Tools.—More advanced lessons on the mechanical principles involved in the use of various tools.

Glue—method of manufacture.

Calculations.—Simple problems in keeping with the lesson given on tools. Determine the amount and cost of material consumed in making the box. Determine the volume of each compartment.

EXERCISE V

A PHOTO STAND

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Geometrical marking out. Shaping with bow saw and spokeshave. Chamfering (cross-grain curves and internal). Rebating with chisel and router (with and across grain).

Instructions.—DRAWING.—Make a freehand sketch of the model, and write in all dimensions. Prepare working drawings as shown. Complete the list of tools and material required.

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Try square. Gauge. Marking knife. Compass. Tenon saw. Bow saw. Pad saw. Brace and centre bit. Firmer chisels (various). Mallet. Router. Spokeshave. Bradawl. Screwdriver (small). Smoothing plane.

Material Required.—Oak, ash, mahogany, cedar, black walnut, satin walnut, or teak; one piece (for front) 9 in. by 7 in. by $\frac{1}{2}$ in.; one piece (for back) 6 in. by 3 in. by $\frac{1}{4}$ in.; one piece (support) 6 in. by 2 in. by $\frac{1}{2}$ in.; screws, two $\frac{3}{8}$-in. No. 4; two $\frac{1}{2}$-in. No. 4; glasspaper.

Benchwork.—STAGES.—

1. Prepare material.
2. Mark out details of front, not including the chamfers.
3. Cut and shape to outline, and mark and cut chamfer at top.
4. Cut out central opening.
5. Make rebate on back.
6. Chamfer central opening.
7. Mark out, cut, shape, and attach support to back piece.
8. Prepare and fix buttons to back.

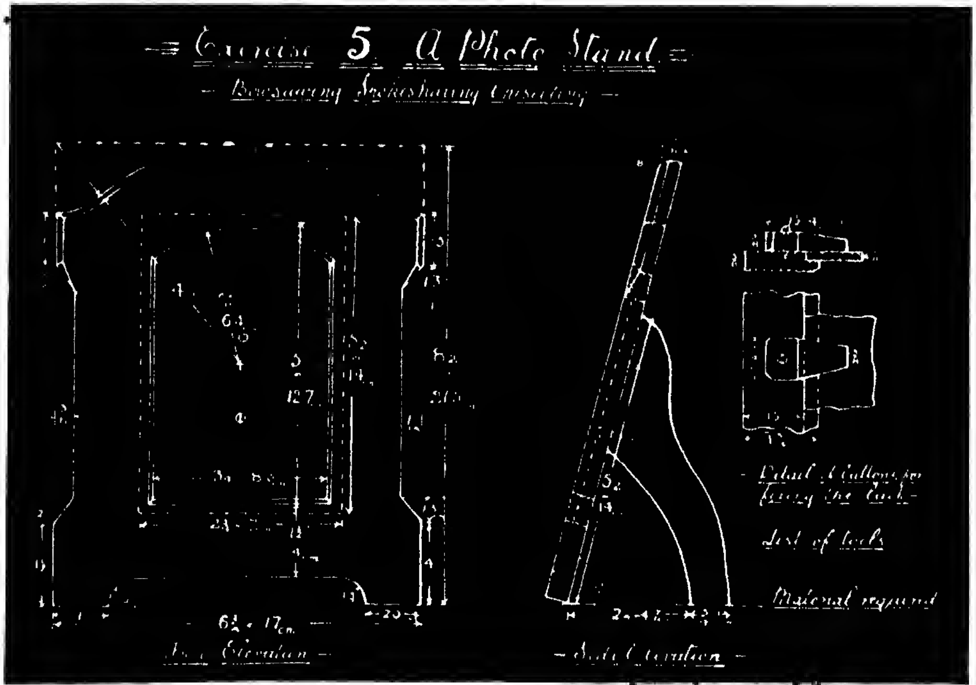


Fig. 294

NOTES

Demonstrations.—

1. Method of cutting central opening.

NOTE.—Small centre-bit holes should be bored at each corner, to allow the blade of the pad saw to enter. Care must be taken, when fixing the work in the vice, to arrange to have the "cross grain" supported; otherwise there is considerable danger of the work splitting.

2. Method of forming rebate on back.

NOTE.—The model should lie on a perfectly flat surface whilst being chiselled.

Lessons: Timber.—Methods of preserving timber—(*a*) when submerged; (*b*) when exposed to variable atmosphere; (*c*) for indoor purposes.

Tools.—Further lessons on the tools used in the exercise.

More advanced problems on the mechanical principles involved in the use of the grindstone.

Calculations.—Determine cost of material used in making the model.

How much glass will be required for glazing twenty models?

What will be the cost of the glass for twenty models, glass being *x*d. per square foot?

EXERCISE VI

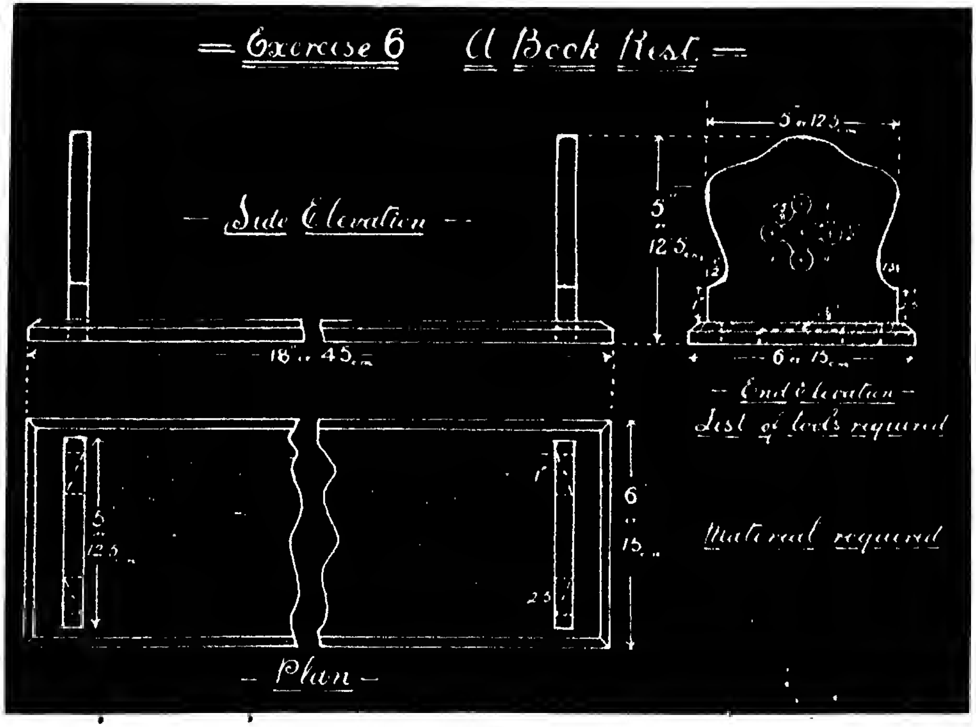
A BOOK REST

Exercises Involved.—Marking out and sawing from the plank. Planing to dimension. Marking out (freehand curves). Mortising. Chamfering. *Double-stopped grooving.* Bow sawing and spokeshaving. Boring. *Internal gouging.* Gluing and wedging.

Instructions.—DRAWING.—Make freehand sketches, and prepare three views as shown. Complete the list of tools and material.

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Trying plane. Try square. Gauge. Marking knife. Mortise gauge. Firmer chisel. Mallet. Chisels (various). Router. Tenon saw. Bow saw. Brace and ½-in. centre bit. Gouge. Hammer. Smoothing plane.

Material Required.—Oak, black walnut, satin walnut, or sycamore. One piece (base) 19 in. by 6¼ in. by ⅝ in.; one piece (ends) 12 in. by 5¼ in. by ⅝ in.; glasspaper; glue.



= Exercise 6 A Book Rest. =
— Side Elevation —
18" or 45 cm
5" or 12.5 cm
5"
12.5 cm
6" or 15 cm
— End Elevation —
List of tools required
Material required
6"
15 cm
— Plan —

Fig. 295

Benchwork.—STAGES.—

1. Prepare material.
2. Mark out, cut, and shape base.
3. Mark out, cut, and shape ends.
4. Clean off, fit, and wedge together.

Demonstrations.—

1. Method of marking out mortises.

NOTE.—It is advisable that these be worked from a central line; also, when marking out the pins on the ends, if the centre line be adopted, the pins and mortises will coincide.

2. Method of working double-stopped grooves. Being short, the sides will have to be chiselled, and the waste removed by means of the router.

Lessons: Timber.—Principles of shrinkage, and influence of medullary rays.

Tools.—Advanced lessons on the tools used in making the exercise. Manufacture of iron and steel.

Calculations.—

1. Find the area of the base.
2. Find the volume of the base, including mortises, chamfers, and grooves.
3. Calculate the weight of the model, having given the specific gravity of the particular wood used.

NOTE.—

Wood.	Specific Gravity.
Oak	·75
Walnut	·60
Sycamore	·59

A cubic foot of water weighs approximately 62·5 lb.

EXERCISE VII

A CANDLE BOX

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Setting out of curves and dovetails. Spokeshave and gouge work. Boring. Chamfering. Screwing. *Hinging.*

Instructions.—DRAWING.—Make a freehand sketch of the model and proceed to complete the views shown.

NOTES

This model affords a good example for an advanced exercise in isometric projection.

Complete the list of tools and material.

Tools Required.—Ruler. Pencil. Half-rip saw. Panel saw. Jack plane.

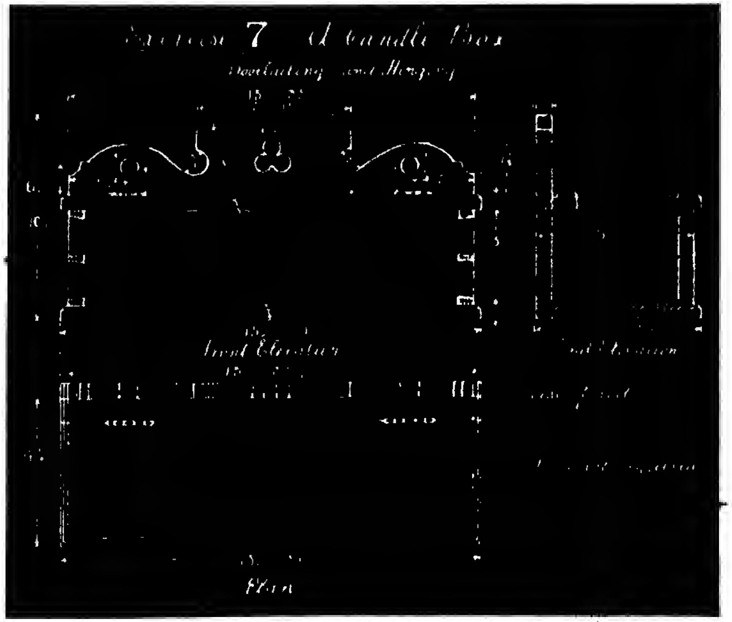


Fig. 296

Trying plane. Try square. Gauge. Marking knife. Bevel. Tenon saw. Bow saw. Spokeshave. Scribing gouge. Brace and ½-in. centre bit. Firmer chisels (various). Bradawls. Countersink. Hammer. Mallet. File. Smoothing plane.

Material Required.—Any hard wood (pine or poplar may be used if desired). One piece (front and ends) 25 in. by 3¼ in. by ⅝ in.; one piece

NOTES

(back) 14 in. by 7 in. by ⅜ in.; one piece (bottom and lid) 28 in. by 5½ in. by ⅜ in.; screws, eight 1-in. No. 8; brass butts, one pair 1-in. with screws; glasspaper; glue.

Benchwork.—STAGES.—

1. Prepare all material.
2. Mark out and dovetail together sides and ends.
3. Mark out, cut, and finish top curves and holes in back.
4. Prepare bottom. Clean off sides of box and attach bottom.
5. Prepare lid. Hinge lid to hanging stile, and fix in position.

Demonstration.—Method of hinging lid to hanging stile.

NOTE.—The lid and hanging stile should be kept in one piece until the ends have been planed and chamfers worked. The piece should be about ¼ in. in excess of the width of the lid plus the width of the hanging stile. When the ends and chamfers have been completed the width of the hanging stile should be gauged from the back edge and the width of the lid from the front edge. The parts can now be separated by sawing between the gauge marks. The edges are next planed down to the gauge marks and fitted together.

Method of attaching Hinges.—

1. Set two gauges, one to the width of the flange of the hinge and another to the thickness of the flange as indicated in sketch (fig. 297).

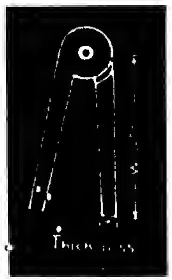


Fig. 297

Fig. 298

2. Mark position of the hinges on piece A. Gauge the width and thickness of the flanges; remove waste and fix flanges of hinges in recesses (fig. 298).

NOTES

3. The hinges are opened and piece A is placed against piece B so that the knuckles of the hinges rest upon B. The opening at E is arranged so as to give the desired amount of 'joint,' i.e. a piece of thin drawing paper placed between the pieces will give the desired amount. A line is then scribed along the side of the knuckles as C to D, which determines the depth to which the flanges should be let in (fig. 299).

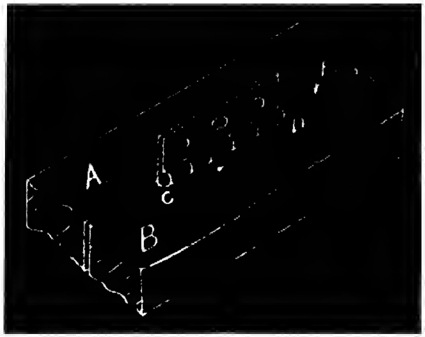


Fig. 299

Lessons: Timber.—Chemical structure of wood, illustrated by simple experiments.

Tools.—Compare the cutting action of the various forms of cutting tools and mechanical principles involved.

Continue lesson on manufacture of iron and steel.

Calculations.—Work problems applying to model as in former examples.

EXERCISE VIII

AN INKSTAND

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Marking out. *Moulding in the direction of the grain and across the grain of the wood. Double-stopped fluting. Boring with expansion bit. Mitre cutting.* Screwing.

Instructions.—Drawing.—From freehand sketches of the model prepare a plan, side elevation, and section, as shown.

Complete the lists of tools and material required.

Tools Required.—Ruler. Pencil. Half-rip saw. Panel saw. Jack plane. Trying plane. Try square. Gauge. Marking knife. Compass. Firmer gouge. Brace, and *expansion bit.* Tenon saw. Small pin bit and countersink. Smoothing plane. (*Small hollows and rounds if these be used for working the mouldings.*)

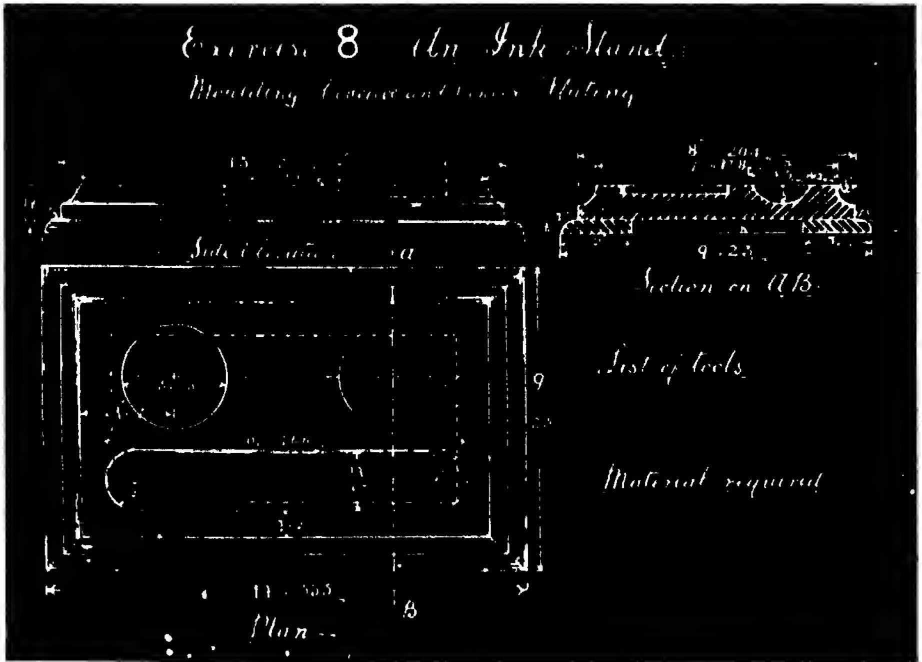


Fig. 300

NOTES

Material Required.—Black walnut is very suitable for this model—other woods may be used at discretion of teacher. One piece (top) 14 in. by $9\frac{1}{4}$ in. by $1\frac{3}{8}$ in.; one piece (base) 48 in. by $2\frac{1}{4}$ in. by $\frac{1}{2}$ in.; screws, ten $\frac{3}{4}$-in. No. 6; glasspaper.

Benchwork.—STAGES.—

1. Prepare material.
2. Mark off length of top, set out holes and flute.
3. Gouge out the flute and bore the holes.
4. Cut off waste at ends of top, sawing very close to the line but leaving a very small margin for cleaning off the end grain.
5. With pencil gauge, mark on lines for hollow along edges and ends. Chamfer down to the lines. Use a firmer gouge and gradually work the hollows, being careful to first complete the hollows across the end grain.

NOTE.—It affords an excellent exercise in the manipulation of the gouge to complete the hollows with the aid of the gouge alone. There can, however, be no objection to the use of a "round" for this purpose, provided it is available. The manipulation of the "round" is in itself a valuable exercise.

6. Clean off "end grain" at ends, using a metal smoothing plane or block plane (if available), taking care to work from the ends toward the centre in order to avoid splitting.
7. Mould the edges of piece for base. This can be done by using a "hollow", or may be finished by using smoothing plane and glasspaper only.
8. Cut and fit "mitres" on base strip.

NOTE.—The mitres may be cut in a mitre box or by the aid of a bevel set to 45°. The shooting of the joints will be done on a mitre shooting board.

9. Fix base pieces in position.

Demonstrations. –

1. Method of working hollows.
2. Method of mitring base strips and fixing in position.

Lessons: Timber.—Closer comparison between the various kinds of woods, and countries from whence obtained.

Tools.—Hollows and rounds, and principles of construction applied to moulding planes in general.

Brief outline of the process of reducing copper from the ore.

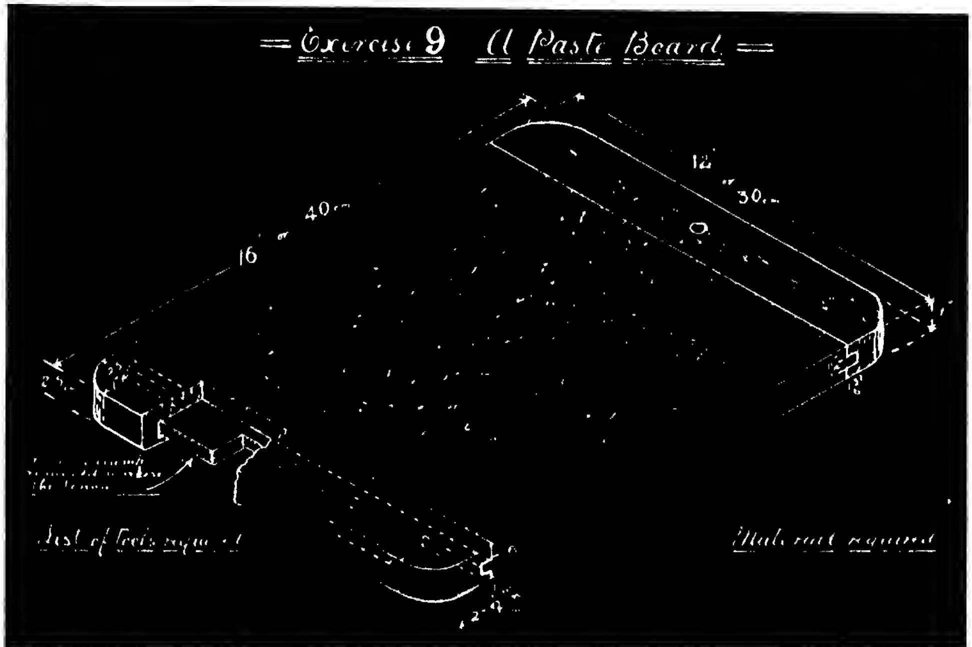


Fig. 301

NOTES

EXERCISE IX

A PASTE BOARD

Exercises Involved.—Marking out and sawing from the plank. *Planing to dimension (large surfaces). Shoulder cutting (long).* Mortising. *Ploughing.* Bow sawing. Spokeshaving. Boring. Cleaning off.

Instructions.—DRAWING.—Prepare plan, elevations, and sections. An isometric projection of one corner of the model would prove very serviceable.

Complete the list of tools and material required.

Tools Required.—Ruler. Pencil. Half-rip saw. Panel saw. Jack plane. Trying plane. Try square. Gauge. Marking knife. Mortise gauge. Mortise chisel. Tenon saw. *Plough.* Bow saw. Firmer chisel. Spokeshave. Brace and centre bit. Hammer. Mallet. Cramp. Smoothing plane.

Material Required.—American white pine. One piece 16 in. by 12½ in by 1 in.; one piece 25 in. by 2¼ in. by 1 in.; glue.

Benchwork.—STAGES.—

1. Prepare material.
2. Set out shoulder and tenons.
3. Set out and make mortises in clamps.
4. Plough clamps.
5. Cut tenons and shoulders.
6. Fit and glue together.
7. Clean off surfaces and cut off waste at ends of clamps. Round corners Bore hole.
8. Clean off ends and edges.

Demonstrations.

1. Method of setting out.
2. Method of holding and using the plough.
3. Method of cutting tenons and long shoulders.
4. Gluing, cramping, and pinning.

Lessons: Timber.—Various products obtained from the timber trees of commerce, and uses to which applied.

Tools.—The plough. Name of parts and use of each.

Metals.—Continue lesson on copper and reduction from the ore.

Several methods may be applied to the treatment of the clamps for this particular model, and the teacher should use discretion concerning the par-

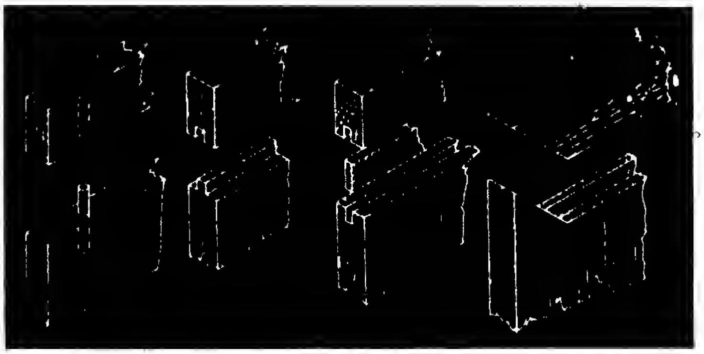


Fig. 302 Fig. 303 Fig. 304 Fig. 305

Fig. 306

ticular method adopted for any class. Various methods might be adopted in the same class, particular scholars being assigned certain methods in keeping with their ability.

The various methods are here briefly defined and illustrated, but for the purpose of the special description above it was assumed that the stopped mortise and tenon would be adopted.

(*a*) Dowelling.—This consists of boring holes and inserting hard-wood dowels (pins). Care must be taken to ensure that the holes are concentric (fig. 302).

(*b*) Groove and Tongue.—This consists of forming a tongue on the piece to be clamped, and making a plough groove along the edge of the clamp (fig. 303).

(*c*) Grooved and Tongued.—The end grain of the piece to be clamped is grooved, also the edge of the clamp. Into these grooves a *hard-wood* cross-grained tongue is inserted (fig. 304).

(*d*) Groove, Tongue, and Tenons. — As described for the exercise, but the tenons are allowed to go through the clamp and are wedged on outer edge (fig. 306).

(*e*) Mitre Clamped.—As described in *a*, *b*, *c*, *d*, only instead of the end grain of the clamp showing on the side of the work the corners are mitred as in fig. 305.

EXERCISE X

A KNIFE BOX

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Dovetailing. Bow sawing and spokeshaving. Boring Chamfering. Nailing and screwing. *Lining with "green baize".*

Instructions.—Drawing.—Prepare plan, side elevation, and section from the isometric view shown.

Benchwork.—Stages.—

1. Prepare material.
2. Dovetail sides and ends together, also prepare grooves for centre partition.
3. Mark out, cut, and fit central partition.
4. Prepare base.
5. Line all inner surfaces with green baize. Glue and fit together sides and centre partition.
6. Clean off outer surfaces of box and fix bottom in position.

Demonstration.—Method of covering surfaces with baize.

Lessons: Timber.—The geographical distribution of forest areas and influence of climatic conditions.

Tools.—Methods of manufacture.

Process of hardening and tempering cutting tools.

Metals.—Zinc and its reduction from the ore.

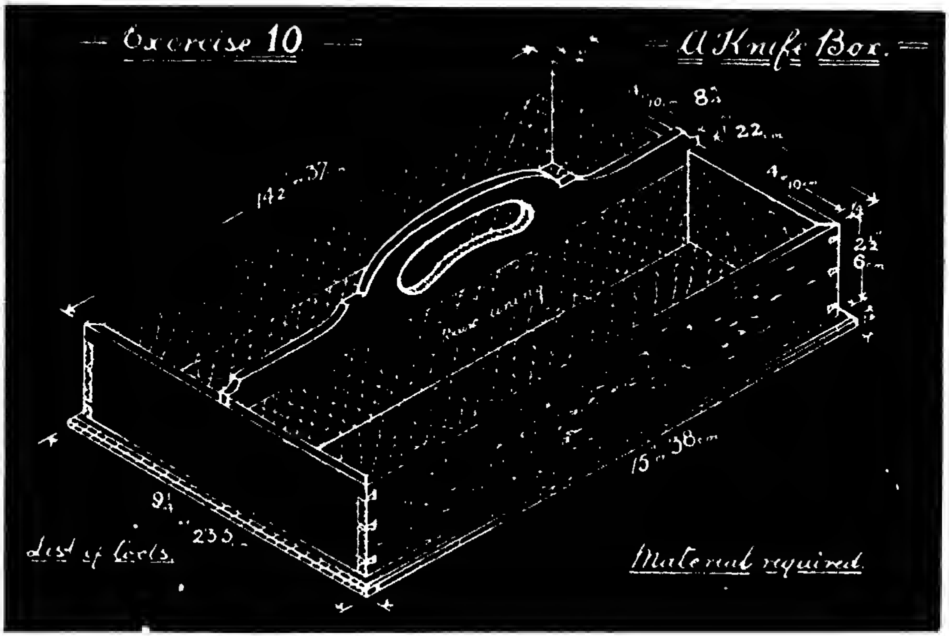

Exercise 10
A Knife Box.
8¾
22 cm
14½" 37
4" 10 cm
2½"
6 cm
15" 38 cm
9¼"
23.5
List of tools.
Material required.

Fig. 307

EXERCISE XI

A ROLLING PIN

Exercises Involved.—Marking out and sawing from the plank. (Thick material.) Planing to dimensions. *Planing to curved form. Planing curved chamfers. Modelling surface having double curvature.*

Instructions.—DRAWING.—Prepare the views shown, together with the centre sections and end elevations, showing the stages through which the work passes.

Complete the list of tools and material.

Tools Required.—Ruler. Pencil. Half-rip saw. Jack plane. Try square. Gauge. Marking knife. Tenon saw. Compass. Smoothing plane. Firmer chisel. Spokeshave (iron). File.

Material Required.—One piece of American pine, birch, or sycamore 14 in. by 2 in. by 2 in.; glasspaper.

Benchwork.—STAGES.—

1. Prepare rectangular prism.
2. Mark centre lines on ends. Shape to rectangular section, working from centre lines and comparing with curve in drawing.
3. Shape to octagonal section.
4. Shape to circular section.
5. Finish with spokeshave, file, and glasspaper.

NOTE.—Test with eye, hand, and drawing.

Demonstration.—Method of producing curved form in each stage.

Lessons: Timber.—Characteristic features of various trees. Bark, foliage, flowers, fruit.

Tools.—Continue lesson on methods of manufacture.

Metals.—Continue lesson on zinc, and reduction from the ore.

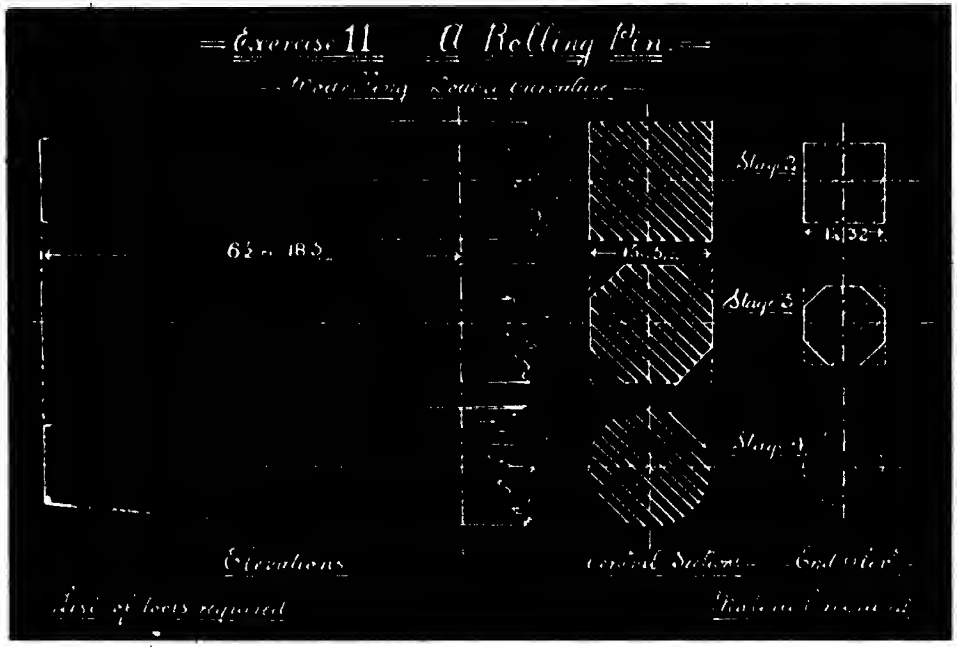


Fig. 308

EXERCISE XII

A HANDKERCHIEF AND COLLAR BOX

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. *Jointing with cross-grain groove-and-tongue joint.* Hinging.

Instructions.—DRAWING.—Prepare the three views shown.

Complete the list of tools and material required.

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Trying plane. Try square. Gauge. Marking knife. Tenon saw. Firmer chisels (various). Mallet. Bradawl. Smoothing plane.

Material Required.—Oak, ash, black walnut, mahogany, or cedar. One piece (sides, ends, partition) 52 in. by 3½ by ½ in.; one piece (bottom and lid) 31 in. by 7¾ in. by ½ in.; one pair 1-in. brass butts and screws; screws, ten ⅝-in. No. 4 (brass).

Benchwork.—STAGES.—

1. Prepare all material.
2. Set out sides, ends, and centre grooves. Cut and form joints.
3. Clean off inside surfaces and carefully glue and cramp the parts together.
4. Clean off outer surfaces.
5. Prepare and fix bottom in position.
6. Prepare and hinge lid to box

Demonstrations.—

1. Method of forming joints.
2. Method of gluing up and squaring the box.
3. Method of blocking the interior whilst cleaning off outer surfaces.
4. Hinging lid.

Lessons: Timber.—Diseases and their causes.

Tools.—Process of manufacture continued.

Metals.—*Brass.*—Composition and manufacture.

NOTE.—This model lends itself to further treatment. The surfaces could be carved or inlaid.

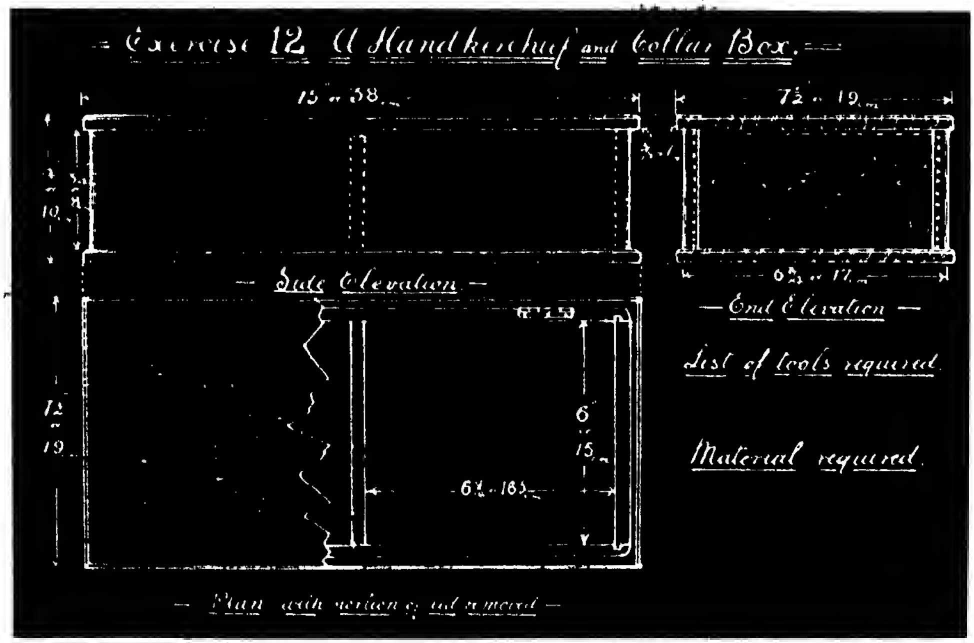

Exercise 12. A Handkerchief and Collar Box.
15" or 38.
7½" or 19.
Side Elevation
6¾" or 17.
End Elevation
List of tools required.
Material required.
12" or 19.
6" or 15.
6¾" or 18.
Plan with portion of lid removed

Fig 300

NOTES

EXERCISE XIII

A STATIONERY CABINET

Exercises Involved.—Marking out and sawing from the plank. **Planing** to dimensions. Bow sawing and spokeshaving. *Dovetailing (small cabinet dovetails).* Shaping and fitting.

Instructions.—DRAWING.—From the isometric sketch prepare a plan, front elevation, and side elevation.

Complete the list of tools and material.

Tools Required.—Ruler. Pencil. Panel saw. Jack plane. Trying plane. Try square. Gouge. Marking knife. Bevel. Compass. Tenon saw. Bow saw. Spokeshave. Firmer chisels. Mallet. Hammer. Smoothing plane. Bradawl. Screwdriver (small). Brace and $\frac{3}{8}$-in. centre bit.

Material Required.—Hard wood or cedar, as selected. One piece (back and bottom) 15 in. by $7\frac{1}{4}$ in. by $\frac{1}{2}$ in.; one piece (ends) 12 in. by $6\frac{1}{4}$ in. by $\frac{1}{2}$ in.; one piece (front) 7 in. by $3\frac{1}{4}$ in. by $\frac{1}{2}$ in.; one piece (partition) 6 in. by $4\frac{1}{4}$ in. by $\frac{1}{4}$ in.; brass screws, six $\frac{3}{4}$-in. No. 4; glue; glasspaper.

Benchwork.—STAGES.—

1. Prepare all material.
2. Dovetail outer framing.
3. Cut and finish curves on back, ends, and front
4. Cut and fit centre partition.
5. Shape and fix bottom.

Demonstration.—None required.
Lessons: Timber.—Defects and diseases.
Tools.—Process of manufacture continued.
Metals.—*Brass.*—General recapitulation.

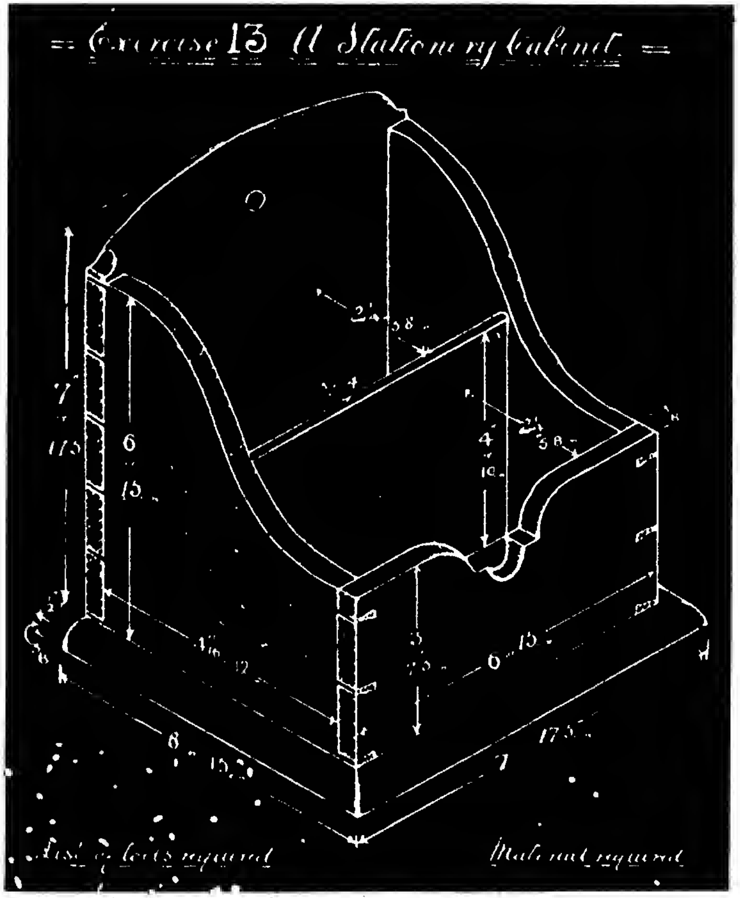

Exercise 13 A Stationery Cabinet
List of tools required
Material required

Fig. 310

NOTES

EXERCISE XIV

A MEDICINE CABINET

Exercises Involved.—Marking out and sawing from the plank. Planing to dimensions. Advanced exercises in marking out work of varying description. Advanced bow sawing and spokeshaving. Stopped grooving. *Framing and panelling as applied to making of door. Lapped dovetailing and common dovetailing as applied to making drawer. Fluting.* Hinging and general fitting together of parts.

Instructions.—Drawing.—Prepare a front elevation and section as shown. Prepare working details of the drawer and various other parts as required. Complete list of tools and material.

Tools Required.—Ruler. Pencil. Half-rip saw. Panel saw. Jack plane. Trying plane. Try square. Gauge. Marking knife. Tenon saw. Chisels (various). Bow saw. Spokeshave. Side fillister. Brace and centre bits. Compass. Mallet. Hammer. Mortise gauge. Mortise chisel. Plough. Router. Bradawl. Screwdriver. Gouge (small). Smoothing plane.

Material Required.—Pine, poplar, selected hard wood, or combination of above.

For Body.—Sides, two pieces 29 in. by 7 in. by $\frac{5}{8}$ in.; top back piece, one piece 16 in. by 12 in. by $\frac{1}{2}$ in.; shelves, four pieces 15 in. by $6\frac{3}{4}$ in. by $\frac{5}{8}$ in.

Apron at Bottom.—One piece, 15 in. by $2\frac{1}{4}$ by $\frac{3}{8}$ in.

Lower Portion of Back.—One piece 16 in. by 15 in. by $\frac{3}{8}$ in. or $\frac{1}{4}$ in.

For Door.—Stiles, two pieces 15 in. by $1\frac{3}{4}$ in. by 1 in.; top rail, one piece 11 in. by $1\frac{3}{4}$ in. by 1 in.; bottom rail, one piece 11 in. by $2\frac{1}{4}$ in. by 1 in.; panel, one piece 10 in. by 9 in. by $\frac{3}{8}$ in.; side pieces, two pieces 13 in. by $1\frac{3}{4}$ in. by 1 in.; one pair $1\frac{1}{4}$-in. brass butts; one small door handle; one small drawer handle; nails; screws; glue.

Benchwork.—Stages.—

1. Prepare material for body.
2. Glue side pieces together with piece of paper between them, in order that both may be worked together.
3. Set out curves, grooves, &c., on side pieces.
4. Cut stopped grooves for shelves. Cut and shape all curves. Rebate back edges.
5. Prepare and fit shelves.

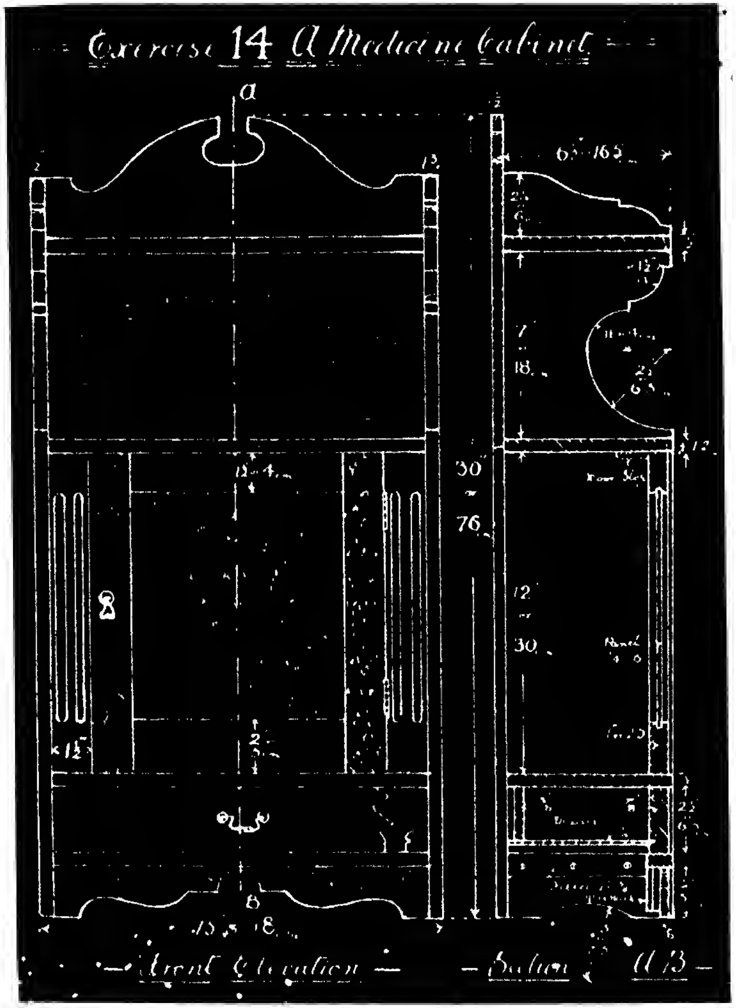

Exercise 14 A Medicine Cabinet
30"
76
12"
30
Front Elevation
Section

Fig 311

6. Prepare top back piece.

7. Clean off all inner faces; glue up, clamp, and nail together the sides and shelves.

8. Fit and fix back piece at top.

9. Fill in lower portion of back.

10. Cut, shape, clean off, and fix apron at bottom of front. Glue block under side of bottom shelf and back of apron.

11. Prepare and fix side pieces (hanging and meeting stile) of door.

12. Prepare all material for door.

13. Set out stiles and rails. Make mortises. Cut tenons. Plough stiles and rails. Cut shoulders. Cut haunchions. Fit together. Prepare and fit panel. Glue and cramp up. Lay to one side to dry.

14. Prepare material for drawer.

15. Set out front, sides, and back, and dovetail together. Plough front for bottom. Prepare side fillets for bottom. Cut and fit bottom. Glue up and nail bottom. Lay to one side to dry.

16. Clean off. Fit and hang door.

17. Clean off and fit drawer.

18. Attach fittings. Clean off outer surfaces.

Demonstrations.

1. Method of fitting panel.
2. Dovetailing of drawer.
3. Fitting fillets to drawer.

Lessons.—General recapitulation.

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